DISCOVERY

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The Progress of Science

The Aeroplane and Scientific Research

RELATIVE to the destruction that aerial bombs have wrought the aeroplane has brought few benefits to mankind. Now the chance occurs to put something into the credit side of the account, and here scientists have a special interest for they need to be able to use aircraft to speed the development of many lines of fundamental research.

Already the physicists of the United States have been provided with planes for cosmic ray research. The aeroplane can help the biologists who are studying the way in which spores of bacteria and fungi are spread by air currents, and already one scientist has devised a trawling device enabling him to take samples of air-borne organisms at great heights—the plankton of the sky, so to speak. Aerial photography makes it possible for the plant ecologist to map vegetation rapidly, though so far it has been little used for this purpose.

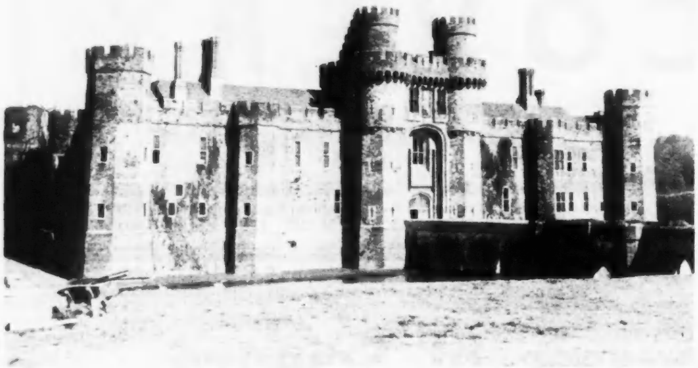
At the recent Aviation Congress held in Paris the part the aeroplane can play as an instrument of research was discussed. A particularly interesting paper was contributed by Professor Marcel Griaule of the Sorbonne, a scientist who is himself a qualified pilot and who has already used aerial photography in connexion with ethnographic research in Africa. The ethnographer is particularly concerned with regions where map-making has not reached an advanced stage, and aerial photography can be of great service. The ethnographer requires records that will show at a glance not only the man-made buildings but also the way in which the land is parcelled out in areas of intensive cultivation, the movements of livestock and the transformation of the environment. Aerial photography can supply such records. The aerial picture is a complete picture; as Professor Griaule says, it needs no conventional signs. Here on the photograph are man's buildings, his division of the land, his crops, his roads, his supplies of water. The aerial photograph enables one to calculate the area of the land under cultivation; the extent and variety of the trees, houses, public buildings, the types of roofs, the building materials used can all be studied. The dams, the canoes, the harvest crops can be enumerated; the apparatus of native industry can be seen.

Professor Griaule also explained the value of aerial photography to the archaeologist. As long ago as 1925 it enabled a French scientist to find the imprint which the Romans left on Syria, and to establish in detail the lines of communication which existed between the Romans and the wandering tribes of the desert regions of the Euphrates. Using aerial photography the same scientist discovered ruins that had vanished under the sea.

Aerial photography can do more than record what is visible to the eye. Where monuments have been levelled to the ground, the camera can pick out the characteristics of the vegetation which grows where the monuments once stood. "Where there were once dung-heaps, stables, embankments or ditches, the vegetation flourishes; where there were roads or the foundations of buildings the plants tend to wither in the dry season," said Professor Griaule.

The aeroplane as a research instrument has not been neglected by British archaeologists, and a lecture to the Royal Geographical Society last year by J. K. St. Joseph (*The Geographical Journal*, Vol. 105, Nos. 1-2, p. 47) gives several examples of the kind of discoveries made in this country through the use of aerial photography. One classic discovery was the revelation of the plan of the Roman town at Caistor-by-Norwich, a chance discovery that came from a photograph taken by the R.A.F. The case of the Roman villa at Ditchley is particularly interesting as it demonstrates Professor Griaule's point about the way crops bring out archaeological features. The first of these photographs (see pp. 226-7) was taken in the autumn; the land is under stubble and there is no visible sign of the Roman Villa. In the second photograph, taken in the summer, the ground is under a crop of wheat and the ground plan of the villa stands out remarkably. To quote the words of Mr. St. Joseph, crops act in the manner of a photographic developer in revealing hidden features.

The applied scientist can also put the aeroplane to good use; geophysicists, for instance, have already worked out a technique for mineral prospecting from the air. Aerial survey can be extremely useful in the economic development



Herstmonceux Castle becomes the new home of the Royal Greenwich Observatory. On the adjoining 370-acre estate the Newton Observatory is likely to be sited.

of backward areas. This was emphasised by Professor Griaule when he spoke of its potentialities in the French Empire. He pointed out that the classical survey methods were too slow and that only by the use of aerial photography could the survey of the French colonies be completed within a reasonable time. The same is true of the British Empire. Even in advanced countries like Canada and Australia there are vast areas still unmapped. In the north-east areas of Canada there are rich mineral deposits which will remain undeveloped until they have been properly surveyed, and this geological and mineralogical survey cannot be begun until a topographical survey has been completed. The Empire Scientific Conference recognised the vital need for perfecting aerial survey techniques, and recommended that there should be a research drive to aim at improving the radar and photographic equipment that can aid aerial survey.

It is interesting to note that last month Sir Ben Lockspeiser, Director-General of Scientific Research (Air) at the Ministry of Supply, suggested that Town and Country planning and agriculture in Britain could both benefit from aerial surveys. He said that all the agricultural land of Britain could be photographed on a large scale—6 inches to the mile—on about 400 magazines of film. He envisaged such an aerial survey, carried out four times a year, as becoming invaluable in the scientific planning of agriculture, which requires continuous records of arable, grass, different types of crops and the distribution of cattle. At present this kind of planning is inseparable from an endless routine of form-filling for which the average farmer has neither the time nor the inclination.

The First Astronomer Royal

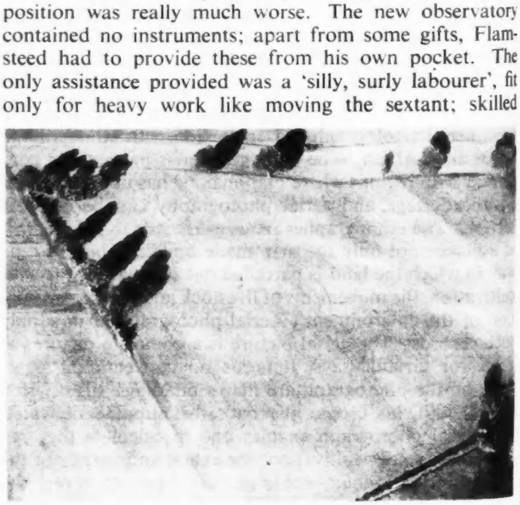
THE Royal Observatory was built in 1675 in pleasant rural surroundings—the nearest straggling outskirts of London were three miles away. Now at last it has been forced to give up the struggle against the smoke and glare of the growing metropolis and seek new accommodation—in Herstmonceux Castle in Sussex. By coincidence the tercentenary of the first Astronomer Royal—John Flamsteed, born on August 19, 1646—gives us a double excuse for recalling the circumstances in which the Observatory came into being.

Everyone interested in the history of science is now familiar with the great importance in the seventeenth century of the problem of determining longitude, especially for a nation like England whose commercial interest in seafaring was coming to dominate her whole economy. Among the proposals for solving the problem was one by a French adventurer, otherwise unknown to history, calling himself the Sieur de St. Pierre. His proposal was based on the method of lunar distances. Charles II referred this proposal to a commission containing such eminent men as Sir Christopher Wren, Robert Hooke, Lord Brounker, Sir Robert Moray, and Sir Jonas Moore, the Surveyor-General of Ordnance. To a meeting of this body Moore brought his young friend, John Flamsteed. He was able to demonstrate to the Commission that any method of finding the longitude in terms of the moon's position was impracticable because neither the existing star catalogues nor the tables of the moon's motion were even within reasonable distance of the required accuracy. On receiving this report, the King exclaimed that he "must have them anew observed, examined and corrected, for the use of seamen".

The outcome was the building of the Royal Observatory at Greenwich, the Royal Warrant for which was dated June 22, 1675. Flamsteed was appointed 'our astronomical observer'.

The total cost of the Observatory, apart from materials obtained from the Tower of London and from Tilbury Fort, was £520. Flamsteed's salary was £100 a year—the modern equivalent would be about £400.

That seems a meagre enough salary, but in fact the position was really much worse. The new observatory contained no instruments; apart from some gifts, Flamsteed had to provide these from his own pocket. The only assistance provided was a 'silly, surly labourer', fit only for heavy work like moving the sextant; skilled



No sign of the Roman villa can be seen in this photograph taken in the autumn.

assistance had to be paid from his own income. Needless to say his stipend would not cover these expenses, and he was obliged to augment it by taking private pupils—in thirteen years he taught about a hundred and forty of them.

Flamsteed's main work was the preparation of an improved star catalogue, though he also took every opportunity to improve the tables of the moon and planets. By 1689 he had made about 20,000 observations. But so inadequate was the equipment at his disposal that the observations referred only to the *relative* positions of the stars. To obtain the data necessary to turn these into useful absolute positions he required an accurate instrument fixed in the meridian. With the financial stinginess surrounding his position, this had to await a chance windfall—namely the death of his father and a consequent legacy in 1688. With this money Flamsteed was able to employ as assistant a skilled instrument maker, Abraham Sharp. Sharp constructed a large mural arc, which marked a great advance in instrument-making, being calibrated with hitherto unapproached accuracy.

The Royal Observatory as it was in Flamsteed's time. It was designed by Sir Christopher Wren "for the observator's habitation and a little for pompe."

Flamsteed was now able to determine such fundamental data as the latitude of the Observatory, the obliquity of the ecliptic and the position of the equinoxes. And on the basis of these he was in a position to put the whole of his past results in useful form. One wonders how many scientists today would be willing to pursue relative observations for thirteen years in the hope that some fortunate chance would provide the means for obtaining the fundamental data required to make them absolute.

Apart from this steadily progressing work on his star catalogue, the rest of Flamsteed's life is chiefly notable for a series of long and involved quarrels with the Royal Society and with Sir Isaac Newton, on such subjects as the availability of his results to others and the question of their publication. To attempt to trace these wrangles in a short space would leave the reader in a state of confusion. Suffice it to say that the blame must be divided. Flamsteed was of an irritable nature, ready to take offence, and his desire to save all his observations until they were complete and then to publish them as a single great work conflicted with the definitely practical objects for which the Observatory had been founded. On the other hand, since he had in fact subsidised the Observatory with his own money, there was some excuse for his looking on the work as his own property and resenting the interference of others.

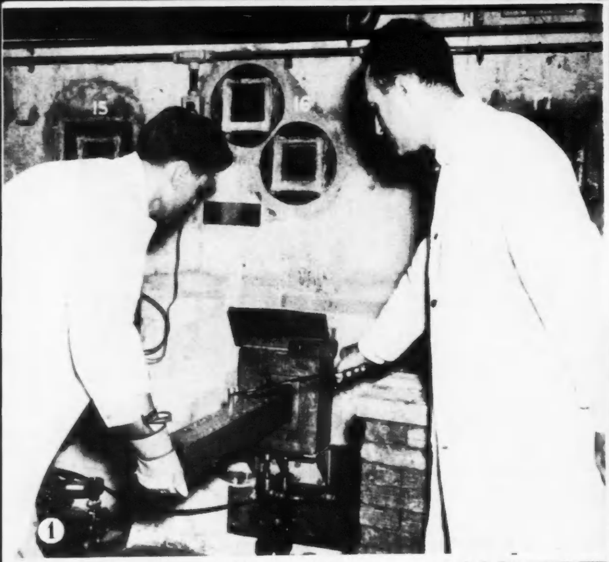
The ground plan of the villa is picked out by a wheat crop. (*Courtesy of Asmolean Museum.*)

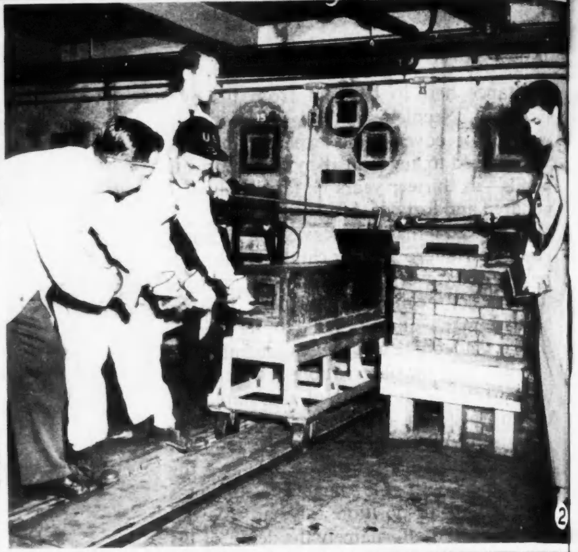
From 1694 onwards he provided Newton with observations on the moon, which the latter required for his work on lunar theory. But the observations were given grudgingly and, apart from being a main source of the quarrels, this was probably an important factor in causing Newton to abandon his work. So difficult did relations become that an imperfect edition of Flamsteed's observations, containing numerous errors, was published—without his consent—in 1712 under the title, *Historia Coelestis Britannica*. On the death of Queen Anne, men more friendly to Flamsteed came to power, and he was able to express his resentment by buying up three hundred of the four hundred copies of the 'pirated' edition and publicly burning them. Thereupon he began the preparation of an authorised edition, but died, before its completion, on December 31, 1719. His assistants finished the work and published it in three volumes in 1725. And thus, from an original excellent intention of Charles II and his advisers, through many unnecessary trials and tribulations caused by cheeseparing economy, there came at last to the world Flamsteed's catalogue of nearly 3,000 stars, a catalogue that opened a new era in sidereal astronomy and set the high standard which the Royal Observatory was thereafter to maintain.

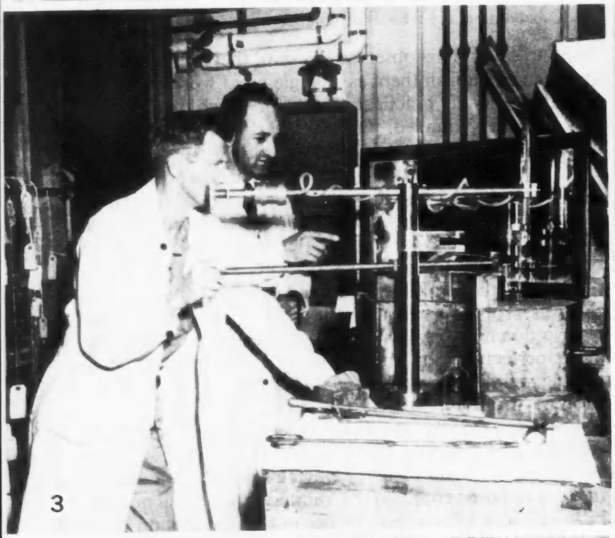
A useful article on Flamsteed can be found in the current number of *Science Progress*, whose reappearance we warmly welcome.

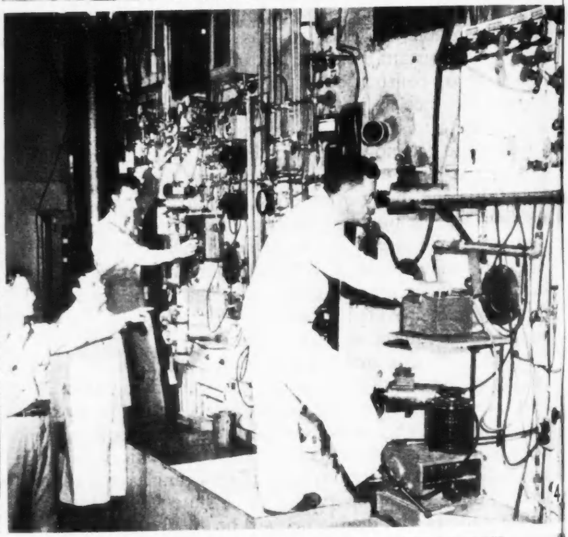
Radio-isotopes from Atomic Piles

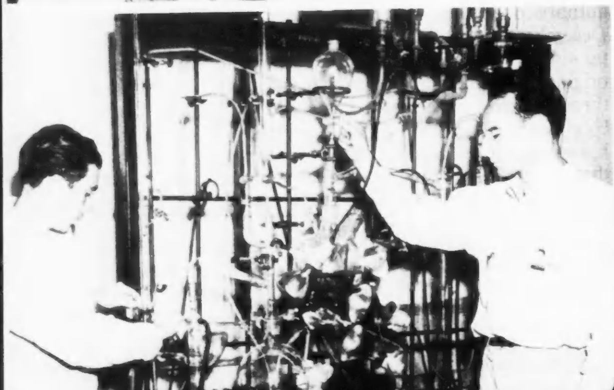
THE cyclotron was a useful source of radio-isotopes and put at the disposal of research workers in medicine, biology and chemistry a supply of 'tagged' or 'labelled' atoms—atoms that can be traced and counted by convenient physical means. But in this field the cyclotron is now

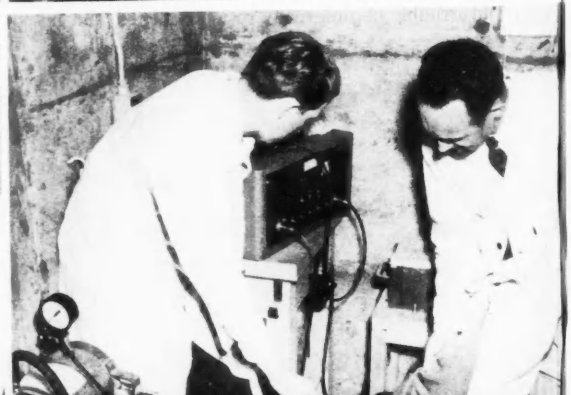












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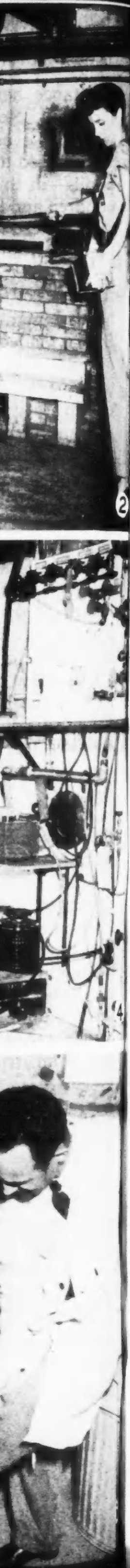


eclipsed by the atomic pile that was devised in connexion with the atomic bomb programme. The uranium chain-reacting pile is far more efficient for synthesising these isotopes which for the first time are becoming available in really large quantities. Whereas a millionth of a gram of a radio-isotope used to be something to talk about, radio-isotopes are now being prepared by means of the atomic pile in grams and, in some cases, kilograms. A month ago it was announced by the U.S. War Department that one hundred isotopes were coming into large-scale production and would be made available to hospitals, industrial and university research laboratories, and medical research institutions.

The photographs opposite show some of the processes involved in isotope preparation by means of an atomic pile.

Most important among the 100 isotopes being released are those of carbon (mass 14), sulphur (35), phosphorus (32) and iodine (131). The supply of Carbon 14 will doubtless give an impetus to the study of all organic processes, including the mechanism of normal and abnormal tissue growth. In the medical field generally these isotopes are likely to yield their greatest benefits not directly in treatment of disease but as tools for finding out the causes of disease.

A Buffer Solution?

A REPORT on the dissemination of scientific information to the general public was prepared by a British Association working party, under the chairmanship of Sir Richard Gregory, for the meeting on July 8 which the British Association held in collaboration with the Royal Society. The working party recommended the setting up of an Institute of Scientific Information, and this proposal is now being considered by the Council of the British Association.

The following functions are proposed for this Institute:

(1) It would maintain in a readily available form a record of all scientific research in Great Britain, in the Commonwealth and in the world as a whole.

(2) The officials of the Institute would be in telephonic or other communication with scientists in every field. It would be their job to find ways and means of obtaining access to scientists with a view (*a*) to securing the latest information in a form suitable for issue to the Press or the B.B.C. and (*b*) to refer to the proper scientific authority any scientific story brought to them by the Press, the B.B.C., etc.

(3) It would supply to the Press and other media complete lists of learned points in pure science, and of technical points in applied science. It would guide pressmen and others in their search for authorities on all scientific subjects.

(4) The Institute would be responsible for keeping the Press and the B.B.C. supplied with a stream of official news releases about scientific matters of interest, whether in the pure or in the applied fields.

(5) Officials of the Institute would be available to advise and recommend on all matters connected with the publicity of science. The Institute would be accessible to producers of scientific films, organisers of broadcasts, planners of exhibitions, local authorities seeking to start exhibitions or museums, etc.

Apart from this organisational proposal, the report contains singularly little that has not been commonplace for years in discussions of the problem. Some of the points in the report that appear to be new do so because they have been recently born in a fertile imagination. Thus in a brief historical survey of the popularisation of science, the early growth of the movement to spread information on the frustration of science by economic and social forces is discussed. This is followed by the interesting statement that "the growth of the belief that science is so shackled led to attempts to transform political economy itself into a science, namely economics". Thus, in one phrase, the works of Ricardo, Adam Smith, Marx and Marshall are erased from the pages of history. Here and there a well-known fact is expressed in perhaps a more than usually striking manner, as for instance, "publicity for young scientists tends to be frowned on by their superiors, and eminent men of science are already busy . . . publicity for scientific information is often associated with enthusiasm for a social or political cause. . . . For an eminent man of science to broadcast about a new discovery may be to invite him to appear either as an unimaginative conservative in the ears of the public, or as an irresponsible politician in the opinion of his colleagues." There we have one of the principal difficulties quite emphatically put.

The proposal for the setting up of an Institute of Scientific Information does not seem to arise as a logical conclusion from the earlier pages of the report in which the various media of publication are discussed and the difficulties that have to be overcome are pointed out. There is, in fact, very little relation between these earlier sections and the final proposal. Indeed there are even direct

FIG. 1.—The outside of the uranium 'pile' at Clinton, Tennessee. A small tube containing a substance to be bombarded with neutrons is being dropped into a graphite block, which is then pushed right inside the pile. After the pile has been started up and operated for a while, it is stopped and the tube withdrawn. The tube will now contain a known radioactive substance which must be extracted ready for use.

FIG. 2.—Here we see the withdrawal of the bombarded tube from the pile. The operator standing nearest the pile is handling the tube with long tongs, while the woman operator on the right checks its radioactivity to see that this is not at a dangerous level. (This particular sample cannot be very active, or it could be handled only behind heavy lead shielding.)

FIG. 3.—The simplest manipulative process becomes very difficult where dangerously radioactive substances are being handled. Here we see the withdrawal of a measured volume of liquid containing such a substance from a lead-encased bottle by means of a remotely controlled pipette, the operation being observed in a mirror.

FIG. 4.—Comparatively simple chemical manipulations are being carried out behind a thick concrete wall, but the remote control mechanisms are quite complicated. Observation is by periscope set into the wall in such a manner that there is no direct route by which gamma rays can reach the operator.

FIG. 5.—Here an apparatus for the extraction of a highly radioactive element is being assembled and tested; it will be installed behind a concrete shield.

FIG. 6.—Clothing and shoes must be examined frequently to make sure that they have not become contaminated with dangerous quantities of radioactive material.

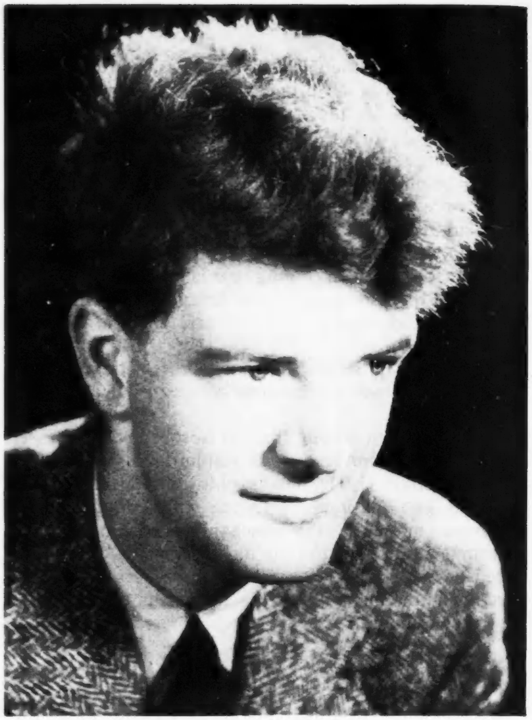
contradictions between these two parts of the document. The section on the Press, for example, points out that a centralised scientific news service, such as that run by Science Service in the United States, would not be practical here, because the concentration of the bulk of the British press in national dailies puts a high premium on 'exclusive' stories and a low value on syndicated material—yet two pages later the proposal for the highly centralised institute is produced, without any attempt to explain how the change from a 'Science Service' to an 'Institute of Scientific Information' would alter this basic fact.

Much more detail about the proposed functions of the Institute is required before one can judge the practicability of the schemes. We are told it is to keep, for the benefit of inquiring publicists, "a record of all the scientific research in Great Britain, in the Commonwealth and in the world as a whole"! When one realises there are 40,000 scientific journals in the world and any one of them will carry at least a dozen papers a year, one begins to wonder whether the working party gave close consideration to this particular point. The Institute is to keep track of the research behind this colossal output. In practice, attempts to keep a record of current research reduce themselves to a series of entries of the form: 'Laboratory A: Director, Dr. X; subjects of research: nuclear physics, magnetic properties of substances, supersonics.' Such information would be cold comfort to any inquiring journalist who would be left where he was—wearing out his finger on a telephone dial in the attempt to track down the particular expert he wanted.

There is no doubt that the committee responsible for the report have acted from the best of intentions. They are quite right in believing that the dissemination of scientific information to the public is in an unsatisfactory state and urgently needs improvement. But it is a hasty and ill-judged reaction to imagine that all can be cured, or even that much improvement can be made, merely by setting up a new organisation. The Institute of Scientific Information savours too much of a rationalised form of the demand made by an editor whom we know who suggested shortly after the first atomic explosion that the world of science should appoint a single public relations officer to keep the Press up to date on all matters scientific.

Two of the points listed above (2a and 4) suggest most strongly that the working party visualises the Institute of Scientific Information as a conventional public relations unit. If so it will have to neutralise the justifiable prejudice that exists against P.R.O.s as a class. In the 'public relations' field in the last few years there has been wholesale replacement of honest fact by sheer propaganda: the hand-outs, and those facility visits which carry with them the penalty of censorship not only of fact but of interpretation of fact, have become little more than buffers to keep journalists and other publicists away from their sources of information. And it must be pointed out that unless the Institute of Scientific Information turned out to be the exception that proved the rule it would be yet one more obstacle to the collection of scientific information.

At this stage the Institute proposal would provide little more than an escape from the real issues involved in this complex question. There are plenty of particular problems forming part of the whole and each requiring its own specific solution; the demand for the Institute



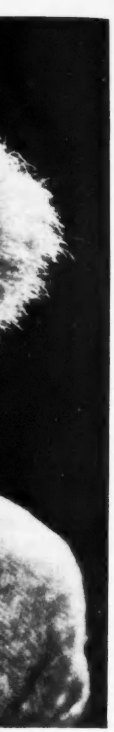
Dr. David S. Evans

draws attention away from them. We can see long-range possibilities in the scheme. Perhaps the scheme is just twenty-five years before its time, in which case our criticisms seen in retrospect will be considered reactionary. Perhaps the scheme contains something practicable today which we have overlooked. If so, Mr. Ritchie Calder, a member of the working party who has promised us an article arguing the case for the Institute of Scientific Information, will have the opportunity of bringing it to the attention of ourselves and our readers.

One of Ourselves

Discovery readers, we feel sure, would like to join us in wishing every success to Dr. David S. Evans in his new post as second assistant at the Radcliffe Observatory, Pretoria. He has just sailed for South Africa to take up this post to which he was appointed at the end of last year.

To Dr. Evans must be given a great deal of the credit for the success Discovery has achieved since it reappeared at the beginning of 1943. The journal had been one of the first war casualties, and to revive it while the war was at its height was no light undertaking. For the first twenty months of its yellow-covered existence there was in effect no full-time editor and the editorial side had to rest on the part-time efforts of three already busy individuals. One of them was Dr. Evans. During that period the whole journal reflected the abundance of enthusiasm and ideas which he brought to it in his capacity of advisory editor. He edited directly the 'Progress of Science' section and wrote many of the items which appeared in it. Through his work for Discovery and on the radio Dr. Evans has proved himself one of the most effective publicists among the younger generation of scientists.



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F A O in Fact

F. LE GROS CLARK, M.A.

THE international Food and Agriculture Organisation, familiarly known as F A O, was born quietly at Quebec in the October of 1945. Its next meeting at Washington in the closing week of May was mainly concerned with famine and for that reason it attracted more attention. It will meet for the third time in Copenhagen on September 2 next. The emergence of such an organisation must surely affect the normal lives of soil scientists, geneticists, food chemists and food technologists. But in what way? What indeed are its powers? What are its prospects?

For forty years or so the International Institute of Agriculture in Rome had been slowly maturing a statistical instrument to the point where we could safely attempt to manage in some measure the world processes of food production and distribution. In the last decade before the war a considerable amount of information was collected on consumption levels in various countries. Most of the published figures are still somewhat conjectural; but they do at least seem to provide us with tables showing the movements of marketable foods and some indication of the levels of output and the standards of food consumption. For practical purposes we can make use of them. The first use we have made of them in our brave new world has been for the purpose of estimating the possible numbers that may starve in the course of 1946. The coincidence is not, however, entirely a matter of chance. It could be argued that, if we had had the foresight to establish F A O late in 1943 (soon after the conference at Hot Springs dispersed), the famine might have been avoided or mitigated. But this is beyond absolute proof; it would have depended upon the willingness of the countries to co-operate for their own salvation.

Providing the Statistical Basis

Since its inception F A O has published little, though it is possible to study its constitution. There are several reasons for this. During the period of the Interim Commission that rooted itself firmly in Washington after the dispersal of the original conference at Hot Springs, the output of literature was large; some of it was official and most of it unofficial, and there was probably little left to say. But it is also fairly obvious that Sir John Orr and his friends are moving cautiously in a confused and unaccustomed climate; they have to make sure of their ground. In September they will have to produce at least two important documents. One is a statistical estimate of the production levels and the food requirements of all the countries affected; the other is a scheme for the long-term measures that might be adopted for raising production levels over the next two or three years.

The issue of these two reports will mark the first testing time of the new organisation. The figures published by F A O will have to be accepted by member countries as authoritative; they will have to displace in public esteem any other figures that may be issued. Only through their agreement to accept the findings of a central statistical office will the various countries signify their readiness to co-operate. Thus what F A O primarily needs is a sound team of food statisticians; and no amount of humanitarianism will make up for the lack of such a team. F A O will stand or fall ultimately upon its mathematics.

So far we are within the strict limits of the constitution. F A O is at present no more than a fact-finding and fact-publishing office. On the basis of its published facts it may issue recommendations. But it has no power to enforce these recommendations upon its member countries. It is not what the Americans call an 'operative' body. That is to say, it is in no sense as yet a *super-national* body; it is not even an *extra-national* body, since it possesses no source of income save through the funds granted it from the budgets of various governments. Its own budget is exceedingly modest; and at least 40% of that budget for the first five years will apparently be derived from the United States and from our own country. The remaining 60% will be contributed unevenly from thirty or forty other countries.

The First Task

It is the primary task of F A O to produce some measure of agreement among a given number of nations. The pattern of agreements that might in theory be concluded becomes very complex. The function of F A O is thus, we might say, catalytic in nature—it is an agency whose mere existence may gradually help to change the whole course of food production and distribution in a desirable direction. Moreover, it is an affair of governments and not one of the associations or federations of producers and consumers. The decisions to be made lie in every case with governments, but their decisions are influenced by the pressure of organised groups of farmers, medical men, consumers and trade unionists. While, then, F A O has no immediate contact with trade or farming organisations, it must necessarily make its appeal to their imagination through all the organs of publicity it may control, for it must rely upon public support within the various countries to secure its ends.

But it is evident that we need to examine more closely the internal structure of the organisation. To say that it is intended to promote the better feeding of the peoples may be well enough; matters are never quite as simple as that. The working team of F A O is naturally composed of men with very varied experience, agronomists, soil scientists, economists and workers in the field of human and animal nutrition. The precise part all these are playing in the *present* composition of the team is a matter of small interest; obviously the permanent staff of the organisation can only be slowly selected, as men are released by their governments for the service. But already we find suspicion among the groups affected that the organisation tends to show a bias towards one or other of the contending interests, whose differences it is the business of F A O to resolve. At the international farming conference, held in London at the close of May, there was a hint of apprehension lest F A O should lean too heavily towards

consumer interests and so help, in effect, to initiate an era of low farm prices. Far more usual among the publicists is a complaint that F A O is, on the contrary, displaying the traditional bias of all such organisations towards the interests of the primary producers, not least the primary producers in the large food-exporting countries.

Conflict of Interests

This indeed seems nearer the fact of the case. The food exporting countries are well represented in F A O, and while they are represented by men who adhere to the principle of an expanding agriculture supported by expanding markets, these men have their own theories of the manner in which this should be achieved. F A O is not merely a food organisation; it is by its constitution concerned as much with the production of industrial crops and fibres, with forestry and with the welfare of farming populations in all countries. That is as it should be, provided only that the organisation does not dwindle into a mere agency for protecting the interests and the incomes of the primary producers, while at the same time devoting some incidental attention to the levels of food consumption. The consumer of food is, after all, an unorganised unit in society; he is no more than any unselected member of the human race. The farmer or peasant is usually a member of a more or less organised group and he is accustomed to compel his government to pay some attention to his grievances.

Primary producers are interested in the problem of surplus farm products. Even in a world of scarcity this remains ironically true. As far as famine or the threat of famine and gross malnutrition are concerned, the problem of the disposal of surplus stocks is the problem that has first to be resolved. It has hung like a shadow over farming policy throughout the whole period of the war. The disposal of unmarketable surpluses of wheat, maize, sugar, bacon, cotton and coffee is a matter that the worker in the field of nutrition may admit to be of basic importance; he is prepared, for instance, to agree that *calories* come first. But it is not a question that stirs him profoundly. For the primary producer in the exporting country, however, it is a matter of the gravest moment. Farmers have fairly long memories and they do not forget the ruin of the depression years and the anxieties of the later 'thirties. Moreover, they have a natural bias against restrictive practices in agriculture. Such practices may yield them a tolerably safe return for their labour; but they are difficult to manage where seasons are so unpredictable and they offer no incentive to the capable man to get the best out of his soil.

Now, the worker in the field of human nutrition may not be at all concerned with *applied* problems; nutrition interests him as merely a part of human physiology. He rarely shows himself familiar with the large transactions involved in marketing so many million tons of wheat or sugar. Where he does become an applied scientist, it is with the complex dietetic problems of primitive folk or selected communities that he deals most competently. The processes of colonisation and migration have disturbed many of the traditional food patterns of the world—and many of these patterns were in any case far from satisfactory. To effect their improvement in however slight a degree is a matter of importance; and for that reason the workers in applied nutrition are at their best in the struggling cultures of Africa or Malaya and among the backward communities of the United States. They usually have a series of minor problems to isolate and study in the prevailing conditions of food deficiency, the local sources of food supply and the cooking and storage practices of the peoples they are examining. This is a mental climate very different from that experienced by the man who is concerned with the raising of crops or the rearing of animals for the market.

But the tendency in the world is always for markets to develop; with the general growth of industrial populations or of communities concentrated mainly on the production of a single crop, the market for food must increase still further. The basic problem is how to provide these populations with the food they need in the variety they need, while at the same time leaving the primary producer well fed and with an income sufficient to provide a stable market for the products of industry. The worker in the field of nutrition cannot resolve this basic problem, and the primary producer is almost equally helpless. The physiologist may, of course, define the nutrient factors in which a given diet is defective; the primary producer may require at least a fair price, a stable or expanding market and a reasonable chance of keeping his soil in good heart. But what can they do more than that? Only the *economist* can suggest in what way the basic problem of securing a stable market may be handled. In brief, F A O has above all to mature a theory of *food distribution*, and it has then to get that theory accepted by a significant number of countries. It is only by tackling the core of the whole matter that F A O will merge its teams of physiologists soil scientists and agrarian reformers into an organic structure. That is its primary task; and so far the reports issued from the Hot Springs Conference and during the period of the interim commission have been singularly lacking in any constructive proposals on the management of food distribution.

The Economist's Role

Yet the problem will be the same whether one is dealing with surplus stocks in the large exporting countries or with the growth of industrialisation in a hitherto predominantly agricultural community. In either case the problem of the growth and consolidation of a secure food market is a complex one; the theory of its growth has to be studied. The food economist is essentially one of those disconcerting people who insist on asking what will happen to retail prices if prices for food off the farm are raised; he asks, moreover, what will be the effect on farm production if retail prices show a serious decline. In some measure the emergence of F A O and the recent establishment of an international Federation of Primary Producers mean simply that we are passing into the period of the agricultural revolution. Farmers and peasants have not only long memories; they have also their demands upon the civilised world. Now, the task of the economist in the face of this agricultural revolution is quite obvious; it is to ensure, so far as possible, that the increased and stabilised farm incomes, which we all agree to be necessary, shall be accompanied by a firm policy of reform in farming

practices and by a steady lowering of production costs. A period of high food prices and of farm subsidies is otherwise inevitable; and these would only defeat their own ends and probably leave the world little better fed than it was before.

But F A O will have to meet each problem as it arises and utilise it for the enhancement of its own reputation. It has no other course it can adopt. The nature of the report on policy that Orr and his colleagues will have to submit early in September is in little doubt. The real cause of the present scarcity has been the apprehension both of overseas farmers and of their governments that they would, soon after the close of hostilities, be confronted with unmarketable stocks of wheat, maize and other products. No adequate attempt was made to assess statistically the need of food that *might* arise in the world after a war of this duration and character. It was not indeed assumed that fats, sugar and animal products would be sufficient for the demand; but it was assumed until the autumn of 1945 that there would be grain enough and to spare. It is the business of F A O to propose a workable method for exercising this fear of surplus. No other practical way of ensuring in 1947 and 1948 the largest harvests on record can be contrived. Without a guaranteed plan for the removal of surplus stocks the harvests will not materialise.

It does not follow that, because the scheme is proposed, it will necessarily be accepted. A guarantee fund will be required, and in the nature of things a large proportion of that fund will have to be secured from three or four countries. But in this first test of its influence F A O will have to rely upon the good sense of the public and upon its own publicity machine. It has at least no need to keep silence; and, as far as we know, the scientific worker who supports such proposals with his voice or his pen lies in no risk of censure.

Need for Integration

We must be clear, in brief, that the international organisation is an affair of governments and that it is bound to express its proposals, if they are to be of the slightest value, in political and economic terms. The food scientist and the agronomist will have to accustom themselves to moving in this still unfamiliar medium. They may be gradually assimilated into it, and indeed it forms the only point of fusion for all their distinct disciplines and modes of thought. There is as yet no integrated science of human feeding; there are a number of sciences waiting to crystallise about a central idea, and it is to provide this central idea that F A O has come into existence.

Let us in conclusion make a few general comments on the world that has at last matured an international food organisation. There can be in the world no single principle that F A O may adopt as a guide to policy. Two main theories of farming reform now dominate the civilised world, and it may be doubted whether they do not represent two distinct and irreconcilable forms of solution. The American plan is for a secure export market in wheat, maize, sugar, bacon and other farm products; it is based on the concept of a world in which trading relations shall develop as freely (or almost as freely) as they do within a country that exists under a commercial economy similar to that of the United States. It is based, too, mainly on the principle of a progressive peasant economy such as exists in some of the western and northern countries of Europe; it contemplates the support of these peasant economies by large-scale hydro-electric and irrigation schemes, agricultural banks and co-operative marketing and purchasing organisations. The Soviet solution does not differ technically from this, but it rests upon the notion of a managed process of reform within a given country or group of countries rather than on any immediate concern with the world market as a whole. It prefers to integrate closely from stage to stage the expansion of farming and industrial production, and it tends to pay special attention to the reconciliation of farm and industrial prices. It sees agriculture as a changing function within society, where there is no necessary stabilisation upon a peasant economy or even at the stage of peasant co-operatives.

The Pendulum of Choice

This conflict of solutions is at present concentrated in the countries of the Danube Basin and of the Balkans; but it will spread slowly through the vast Asiatic societies. The conflict is not strictly a political one, though it has its political aspects, it is purely a conflict between two possible processes of agrarian reform.

In a world with two conflicting patterns of solution for the food problem, F A O can pursue no single orthodox policy. It will have to adapt its plans to the varying conditions that prevail from country to country. The Soviet solution is perfectly practicable, because it is more modest and allows for the chance shifts and set-backs that may accompany any process of agrarian reform. The American solution is more doubtfully practicable. It rests upon too great a number of assumptions, and it makes the basic error of supposing that an inherently unstable economy, such as that of the United States, can be stabilised by the simple expedient of spreading it over a number of countries and making them more or less interdependent. F A O cannot afford to take sides. It is a scientific entity and, so far as it is later granted executive or operative powers of any kind, it must use them to apply well-established scientific principles. It will have to adapt its practice to the trends within any given country.

So much for a fragmentary descriptive treatment of this new species of organisation. The scientific worker may now study its substance and growth further for himself. It is a symptom of our scientific maturity that we can at last achieve such an organisation, but the grasp of food statistics, like the penetration of nuclear physics, resembles the legendary fruit. It is pregnant with the foreknowledge of good and evil. Between the poles of world famine and of a world free from want swings to-day the pendulum of our common choice.

Continued from page 210

The Physics of the Sun

DAVID S. EVANS, Ph.D., F.Inst.P.

It is convenient at this point to consider the type of solar observations which may be carried out at a total solar eclipse of the sun. Until Lyot's work these occasions, affording a total observation time of only a few minutes per year, represented the only opportunities for observation of the prominences in integrated light, and of the corona. As is well known, at its average distance from the earth the moon has almost exactly the same apparent size as the sun, and it is a most fortunate coincidence that in the comparatively infrequent occasions when the sun, moon and earth are in line, the obscuring shutter provided by the moon should be just large enough to cover the actual disc of the sun, and yet not so large as to obscure also the prominences and inner corona. The size of the shadow patch produced on the surface of the earth by the moon during a total eclipse is an oval with dimensions of at most two or three hundred miles. While eclipse conditions persist this moves across the surface of the earth tracing out a narrow track, and an observer within this track will see the sun obscured completely by the moon for a matter of a few minutes at most.

The observed sequence of events is as follows: the moon, which presents its dark side to the earth, and is therefore new, is invisible until it begins to pass before the sun. A circular indentation appears on the solar disc and gradually grows. Just before totality is reached the sun is seen shining along the valleys of the lunar surface, appearing as a series of beads of light (Bailly's beads). (Fig. 23.) Then, finally, the direct sunlight is cut off and the prominences can be seen, red coloured, standing out from the solar surface. There is also to be seen a faint pearl-white cloud, the corona, extending for a million miles or more from the sun, the shape of which varies with the sunspot cycle; at sunspot maximun it is little more than a uniform cloud surrounding the sun, at sunspot minimum it includes a delicate system of fine streamers extending from the poles of the sun. Just as totality approaches the light from the sun begins to be confined solely to the very uppermost layers of the solar atmosphere, and at this moment a change comes over the solar spectrum. As has already been indicated, the solar spectrum consists of many lines seen as dark (absorption) lines on a bright background. This is the characteristic appearance of a spectrum produced by the flow of radiation outwards through layers of cooler gases. Just before totality the spectrum is reversed; the lines change from absorption lines to bright lines. Spectra of this latter kind are characteristic of thin layers of gas shining by their own luminosity, as distinct from illumination arising from a hotter source and passing through a cooler layer. Such spectra can be seen, for example, in the gas of discharge tubes when excited by an electrical discharge. The layer which produces this reversed spectrum is known as the *chromosphere*, and represents the uppermost layer of the sun's true atmosphere.

It will readily be seen that if during this short period of spectrum inversion (which ends when the chromosphere itself is hidden by the moon) the spectrum is recorded on a photographic plate moving perpendicular to the dispersion information can be obtained as to the distribution of various chemical elements with height. For example, hydrogen and calcium are found to extend to relatively great heights above the solar surface, so that the layers of these substances will continue to emit their spectral lines after the layers of other elements are obscured by the moon. Thus lines due to these elements will appear longer on the final moving plate spectrogram than the lines of other elements which are confined to low levels. (Fig. 24.)

Calcium and hydrogen extend to heights of the order of 10,000 kilometres above the point of inversion, a conclusion which is puzzling in the extreme, and many explanations, none completely satisfactory, have been advanced in attempts to account for these observations. The calcium is in ionised form, and Milne suggested a mechanism depending on the pressure exerted by the radiation absorbed in two strong lines in the ionised calcium spectrum. While this would provide support for the calcium, it would be ineffective for other elements. Mere hydrostatic equilibrium, that is, the support of each layer by the pressure of those below, would be quite unable to account for the observed extent of the chromosphere; variants of Milne's theory have suggested that the calcium carried the hydrogen along with it, but this view is open to serious objections. At the moment, the theory which holds the

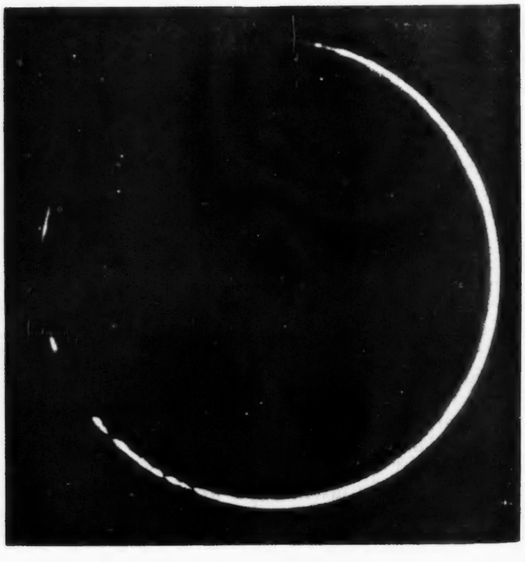


FIG. 23.—The sun almost completely eclipsed, showing sunlight down the lunar valleys.

field involves the idea that the gases in the chromosphere are in turbulent motion, and that the elements are kept up by this large-scale mixing, but it cannot be maintained that this hypothesis is entirely convincing. The phenomena have certain features in common with those exhibited by the prominences, and those which are exhibited by the corona; the atoms not only behave as if the force of gravity were reduced or balanced by some other type of force, but, in addition, the atoms concerned exhibit properties suggestive of temperatures a good deal higher than those obtaining at the actual surface of the sun. This is, of course, an anomaly, since we are accustomed to associate high temperatures with the interior of the sun, not with regions high above the solar surface.

The Solar Corona

The solar corona is one of the most baffling of the appendages of the sun. As already stated, it is of a pearly white colour, and it emits a total radiation of only a few millionths of that of the sun and is comparable in brightness with the full moon. Its variation of structure with the sunspot cycle (Figs. 25 and 26) was recognised from eclipse observations many years ago, and the spectrum, showing bright lines, has been obtained at a considerable number of eclipses. Until recently it was not possible to identify the elements responsible for these lines, and it had even been suggested, by analogy with helium, first discovered in 1868 by Lockyer who observed its spectrum in prominences, that a hypothetical element, 'coronium', might be responsible. The coronal lines seemed to be unique until, some years ago, some of them were observed in the spectrum of a nova, an exploded star, in which conditions of very high excitation must have obtained. During the recent war the lines were identified as due to highly ionised atoms of iron, nickel, calcium and argon. The identification, made by Edlén, a Swedish spectroscopist, was based on the study of atoms having similar systems of electrons. For example, the hydrogen atom, having one electron, has a spectrum very similar to that of ionised helium. Normally helium has two electrons but, when one has gone as a result of ionisation, conditions in the ion with its one remaining electron bear a considerable resemblance to those in the neutral hydrogen atom. In the same way, any neutral atom produces a spectrum having some similarity to the spectrum of the once ionised atom next to it in the table of elements: both atoms, one neutral, the other deprived of one electron through ionisation, have the same number of electrons and the similarity in spectrum is due to the fact that it is the electrons which produce atomic spectra. The spectrum is also similar to that of the atom next again deprived of two electrons, and to that of the subsequent one deprived of three electrons, and so on. From his studies of atoms stripped of as many electrons as possible by laboratory methods, Edlén was able to argue further and to deduce the spectra of still more highly ionised atoms occurring later in the table of elements. In this way he was able to identify the observed coronal lines as due to atoms of nickel, calcium, and argon deprived of from nine to fifteen electrons. This result, a scientific *tour de force*, merely opens up new problems. Ions of this extraordinarily high degree of electron loss might be expected to occur only in regions

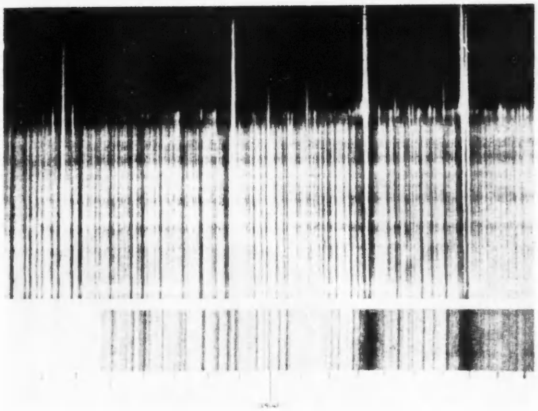


FIG. 24.—The spectrum of the chromosphere. The plate moves down during the exposure and the point at which the normal spectrum of the sun (dark absorption lines) is replaced by the spectrum of the chromosphere (bright lines—the flash spectrum) can clearly be seen. The reversal lasts for a few seconds after the disc of the sun is hidden by the moon and before the upper atmosphere of the sun is covered. The hydrogen lines extend to great heights above the solar surface. (*From "The Sun" by Abetti, by courtesy of the publishers, Crosby Lockwood & Son.*)

where the temperature was of the order of half a million to a million degrees, and it is most unexpected that they should be found far above a star whose temperature on the surface is only about 6000 degrees.

Observational studies of the corona have been tremendously advanced by the work of Lyot, whose primary object in constructing the instrument already described was to render the corona visible in the absence of a total solar eclipse. He has been able to extend observational knowledge of the coronal spectrum enormously, and in addition has produced a number of remarkable photographs of the inner corona; Fig. 27 shows one of these. With his original equipment the observations possible still needed to be supplemented by eclipse observations, since he was not able to observe the fainter and more distant parts of the solar corona.

However, during the war, he brought to perfection a piece of optical apparatus of the most extraordinarily ingenious kind. This cannot be described in detail, but suffice it to say that it has the same ultimate object as his earlier method and as the spectroheliograph, namely the isolation of particular bands of radiation in which the corona is sufficiently strong compared with the sun to be rendered visible. The arrangement is a sort of optical analogue of the radio band-pass filter transmitting a number of selected frequencies, and by a brilliant stroke of design which confirms his position as one of the leading opticians in the world, he was able to select as his frequencies those corresponding to two strong lines in the corona and strong lines emitted by prominences, together with an additional frequency which was used for guiding by eye observation. His work represents a tremendous forward jump, and surpasses even that achieved by his earlier work. His latest photographs show detail of fine arches in the corona and successive

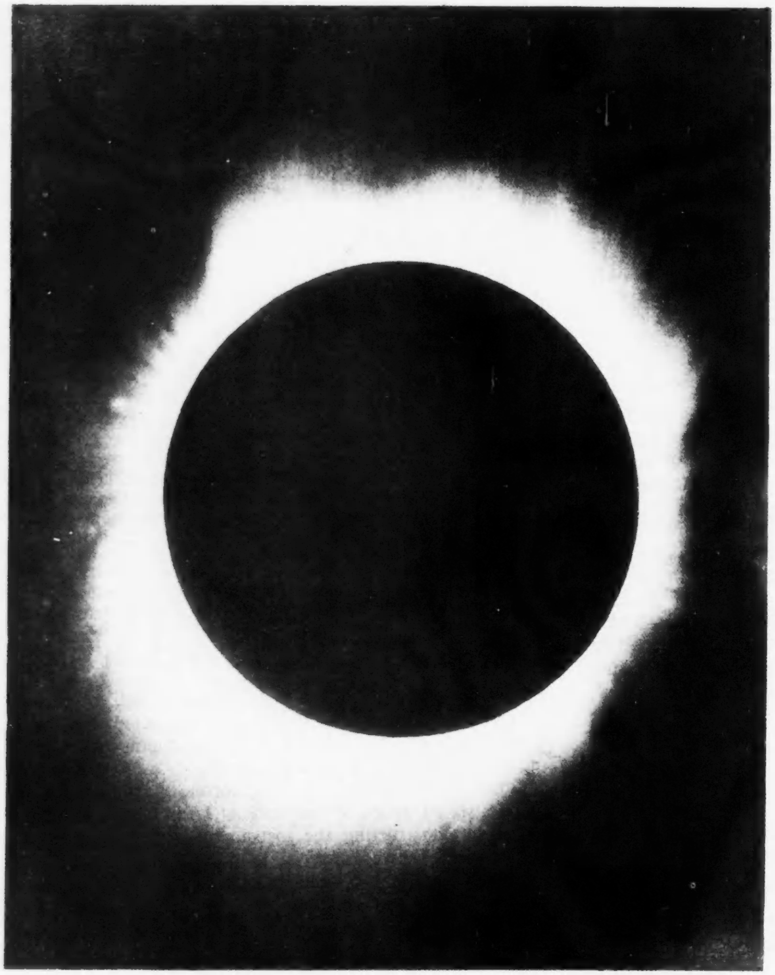


FIG. 25.—The corona at sunspot minimum (1900).

pictures show the changes which occur, which are due, not to movements of gas, but to the fading and brightening of areas withing the corona. Even more startling, he has obtained with this new apparatus, which shows the disc of the sun as well as the sky round it, photographs showing the chromosphere as a definite thin line of light. It had perhaps, begun to be thought that the terms, photosphere, chromosphere, etc. referred to purely conventional divisions of the solar atmosphere, but it now seems that the chromosphere at any rate is a true, physically distinguishable layer. (Fig. 28.) With the same apparatus he has also obtained photographs of sunspot groups on the solar disc which have a definition probably unequalled by any other photographs of such subjects ever previously taken.

This completes our rough survey of the appendages of the sun, and its surface appearance, but does not exhaust the possible information which can be obtained about the sun as a whole. Studies of conditions in the interior of the sun are, of course, dependent on methods even more indirect than those already sketched, and are subject to a far greater degree of uncertainty, but it is nevertheless possible to discover a quite respectable amount of information about the deeper layers.

As already mentioned, it is possible to estimate the effective temperature of the solar surface by comparing the total energy emitted with the energy emitted from bodies at various temperatures, the latter being based on well-tested theories of radiation. Other comparisons are also possible; radiation laws predict not only the total energy emitted at each temperature from unit area of the surface of a body, but also its distribution in various colours. It is found that the sun does radiate approximately as a theoretical body of the type known to physicists as a black body and the temperature derived in this way—the colour temperature—is roughly in agreement with the effective temperature determined by the method already explained.

Further estimates of temperature are, however, possible from a study of the spectrum of the sun. This consists, as has already been noted, of a series of dark lines on a bright background, each element present producing its own set of lines. The capacity of particular atoms for producing their spectra depends on the fact that they absorb (due to details of atomic structure which can not be explained here) particular colours of radiation characteristic of the given atomic species. This absorbed radiation is later re-emitted, and the atoms are then in a state to repeat the process. It might be thought that the re-emission would just compensate for the original absorption, but, under solar conditions, this is not so. The absorbed radiation is extracted from a stream flowing out from the centre of the star towards the surface, whereas the re-emitted radiation is sent out from the atoms in all directions. Only a part of the re-emitted radiation has the direction of the original outflowing beam, so that, on balance, the radiation coming from the surface of the sun is defective in the particular wavelengths (colours) which the atoms have a special propensity to absorb. In this way there occurs a reduction in these particular wavelengths and the characteristic spectra of the atoms present are printed on the sunlight.

However, the degree to which this takes place depends on the number of atoms of, say, hydrogen or helium, which are in a condition to absorb. If the temperature is so high that most of the helium atoms have lost an electron,

then, in spite of the fact that many helium atoms may be present, few will be in a state to produce the spectrum of neutral helium, and this will therefore be weak; on the other hand, in these conditions, many helium ions will be present, and the ionised helium spectrum will be strong. Since an increase of temperature tends to ionise atoms, there will be a general tendency in stars of higher temperature for the spectra of neutral atoms to be replaced by those of ions, while those of singly ionised stoms will fade at the expense of doubly ionised atoms.

The progress of this process of replacement is calculable theoretically, and it is possible, not only to determine the temperature to which a given complexion of line strengths corresponds, but also to determine the real abundance of elements in the solar atmosphere. For example, hydrogen shows a weak spectrum in the solar atmosphere, but it turns out that the temperature is too low for strong hydrogen lines to appear. There is present far more hydrogen than a mere superficial study of the line strengths would indicate. The conclusion is in fact the extreme one that there are present something like 3000 hydrogen atoms for every atom of any other kind. The temperatures determined from these studies differ from those determined in other ways. If the gases of the sun were contained in an insulated enclosure kept at 6000° K all these various temperature determinations would be equal (all giving a value of 6000° K); the fact that the estimates for the sun are different is not an indication that the determinations are inexact and that greater agreement might be secured by more refined methods; it is an indication of the fact that conditions in the sun show a departure from the ideal conditions which obtain in an insulated enclosure, and this constitutes an encouragement to study the observed differences as a way of discovering the more subtle features of conditions in the outer layers of the sun.

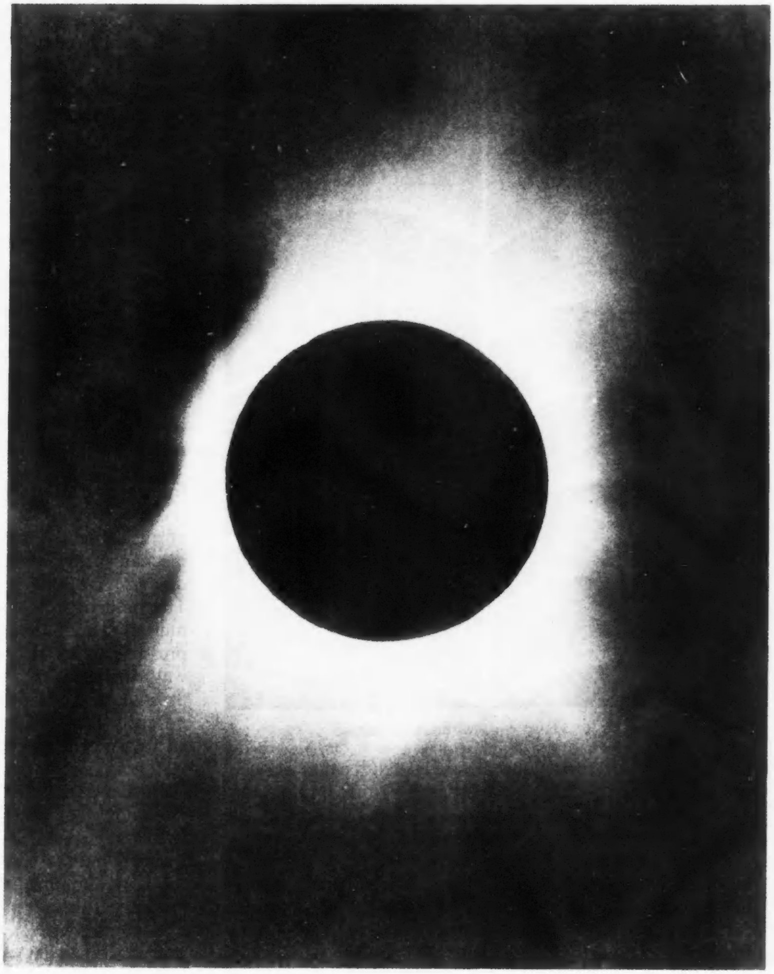


FIG. 26.—The corona between sunspot minimum and maximun (1925).

The composition discovered by these spectroscopic analyses shows the presence of the following substances in the proportions given:

Non-Metals		Metals			
Hydrogen	300,000	Magnesium	63	Potassium	6
Helium	1,000	Silicon	20	Calcium	5
Oxygen	1,000	Iron	16	Aluminium	3
Nitrogen	40	Sodium	16	Nickel	1
Carbon	25				

It is accepted, at least as a working hypothesis, that the metal mixture adopted here (which is due to H. N. Russell) is the standard recipe for star material, although there is some uncertainty about the relative proportions of the Russell mixture and hydrogen. One peculiar fact which should be noted is that the elements of even atomic number (including rare elements not included in the above list) are roughly ten times as abundant as those with odd atomic numbers.

When we come to consider conditions deep in the sun's interior our only method of investigation is to construct theoretical models and comparing their behaviour with the observed behaviour of the sun. To do this an imaginary star is constructed by aggregating together a number of lumps of gas. The material holds itself together by its own gravitational attraction, and, as we add more and more gas, the pressure and temperature at the centre increase. Each part of the star must, in fact, support by its pressure the force with which the whole star attracts the material above. Here it should be mentioned that pressure is of two

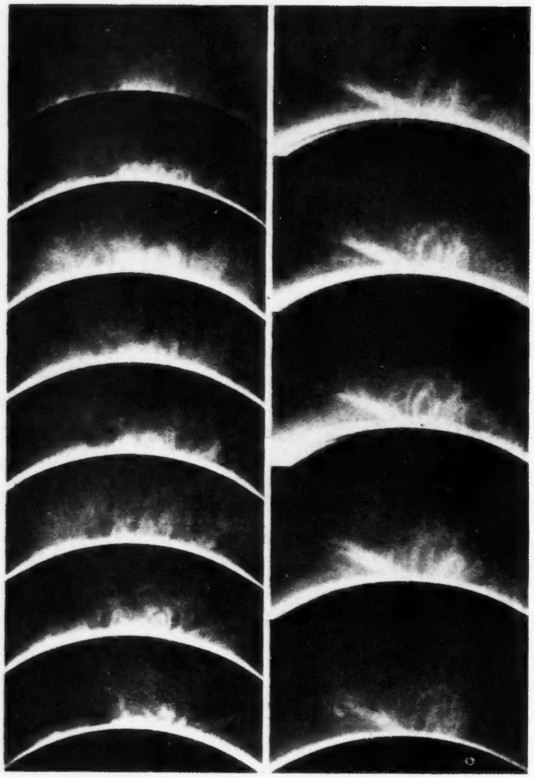


FIG. 27.—The corona without an eclipse.

kinds: one the familiar gas pressure such as that exerted by the air in a bicycle tyre: the other, pressure of radiation, a notion foreign to our ordinary experience where we are concerned only with low temperatures. At high temperatures the pressure which can be exerted by the intense outward flow of radiation becomes so great that it serves to support a considerable part of the inward gravitational force, whereas, for example, the total pressure of sunlight falling on the earth is less than two pounds per square mile. It must also be mentioned that some support is also derived due to the fact that the interior of a star has an electric charge distributed throughout the material, which tends to blow the star apart and neutralises approximately half the gravitational force.

In this way it is possible to estimate the central temperatures of stars, which are found to be of the order of 20 to 40 million degrees. At temperatures of this degree of elevation, all the electrons have been split from their parent atoms and most of the chemical differences which complicate matters at ordinary temperatures have been rubbed out. The signal exception is hydrogen, and it is found that the variation of the proportion of hydrogen in a star has a marked effect on the brightness of a star of given size. If we manufacture a theoretical sun we find that a sun of the correct mass size and luminosity can be made only if we assume that it contains about 33% of hydrogen by weight—or about twenty hydrogen atoms for each atom of every other kind. This is considerably less than the proportion at the surface, a feature which may perhaps be explained by certain theoretical studies which suggest that the hydrogen in stars may tend to concentrate near the surface, but it does mean that the sun is in reality a globe of hydrogen, containing as impurities about 5% of other substances. The prominence of the metals and heavier elements in the solar spectrum is due solely to the effects of surface temperature which are favourable for the production of their spectra and unfavourable for the production of the hydrogen spectrum.

The discovery of this great preponderance of hydrogen in the composition of the sun (and, it is thought, of stars in general) which was made some fifteen years ago, immediately set off a train of speculation on the problem of the source of the sun's energy. As we have already seen, the temperature at the surface of the sun is so high that no chemical compounds can persist, so that there is no question of the sun being a burning body. It is also, incidentally, quite easy to calculate how long the sun would be expected to burn if it were on fire; the conclusion is that the sun would have a lifetime of only a few hundred years, which is palpably far too short.

If, as we believe, the earth was once part of the sun, then the sun must have been in existence for at least as long as the oldest rocks of the earth, that is, for a period of time of the order of 1000 million years. There is a second mechanism by which the sun might, and almost certainly did at one period, gain energy, namely, contraction. The tendency of matter in a star to fall together due to mutual gravitational attraction has to be resisted by pressure from within. If a star were to contract in this way, the gases of which it was composed would be compressed, and their temperature would rise, just as the air pumped into a bicycle tyre is heated by compression. In this way a star could convert its gravitational energy into heat energy by contracting in upon itself. However, even if the star started from a state of infinite dispersion the amount of energy which could be secured in this way is strictly limited, and, in the case of the sun, contraction from an infinite size to the present diameter would suffice for only about 20 million years' supply of energy at the present output.

The discovery of the preponderance of hydrogen suggested that the source of stellar energy would be atomic energy derived, it was initially thought, either from the annihilation of matter, or the conversion of hydrogen into

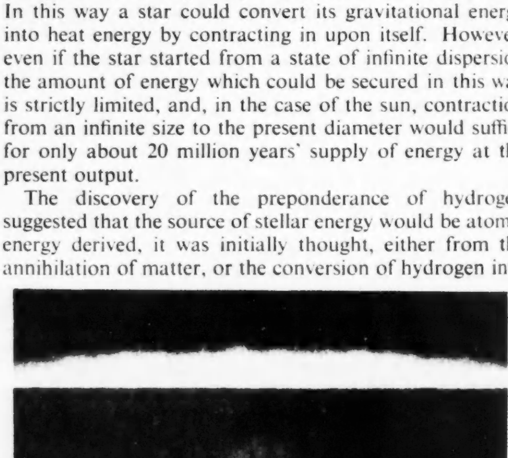


FIG. 28.—The chromosphere.

some other element. The first hypothesis has been dropped, and it is now thought that the energy-producing process in the sun is the conversion of hydrogen into helium.

In atomic units the mass of a hydrogen atom is 1·008 while that of a helium atom is 4·004. If we could in some way, persuade four hydrogen atoms to unite together, there would be a mass excess of ·028 units. It is known that if in any process mass disappears, energy appears in its place, in the proportion of 9×10^{20} ergs for each gramme of matter lost. It can be appreciated how large this energy liberation is when it is stated that this production of 9×10^{20} ergs for each gramme of matter annihilated represents a quantity of energy sufficient to run a 4000 horse-power engine for a year. Thus the conversion of one gramme of hydrogen into a gramme of helium would be accompanied by the liberation of about 6×10^{17} ergs of energy. The process cannot be achieved directly, but according to Bethe and Gamow, is an indirect one in which, in stellar interiors, the synthesis is effected in several stages. (Fig. 29.) A carbon nucleus first picks up a hydrogen nucleus, the two uniting, with liberation of energy to form a nitrogen nucleus. This then splits up by emission of a positive electron into an isotope of carbon; acquisition of a second hydrogen nucleus, gives an isotope of nitrogen, with emission of energy, and this, picking up a third hydrogen nucleus, gives, again with emission of energy, an isotope of oxygen. The latter emits a positive electron, the residual nucleus being an isotope of nitrogen, and this picks up a further hydrogen nucleus, the combination breaking down to give the original carbon nucleus and a helium nucleus. In this way the carbon atom acts as a carrier, to which the successive hydrogen nuclei become attached, until, when four have been picked up in succession, the added particles split off as a helium nucleus. This somewhat complex process is the only one which postulates only atomic processes which have actually been observed in the laboratory, and which, in addition, proceeds faster forward than backward and at about the right rate.

The reason why these processes can go on in stars is that their central temperatures of 20 to 40 million degrees are so high that the atomic nuclei are moving with speeds comparable with those used in atom smashing experiments, and, when collisions occur between them, the nuclei can interact and become changed by transmutation into new nuclei. However, a simple calculation shows that the speeds attained by the average particle are a good deal lower than those which can be given to experimental particles in the laboratory. Man has outstripped nature by a long way in the production of high speed particles, and it may be a little puzzling to see how the slow natural particles can produce so much energy. In the laboratory, when thin metal films are bombarded with high speed particles, the number of successful hits produced is very small, of the order of one success for each million particles projected. The essential difference in conditions in a star is that the number of bombarding particles, in effect all the hydrogen nuclei which are present, is very large, and further, conditions are such that in the end every particle is bound to make a successful collision. Man may be able to produce faster particles, but these are limited in number and lose their energy when they collide with the cool walls of the apparatus. Nature makes her apparatus out of hot

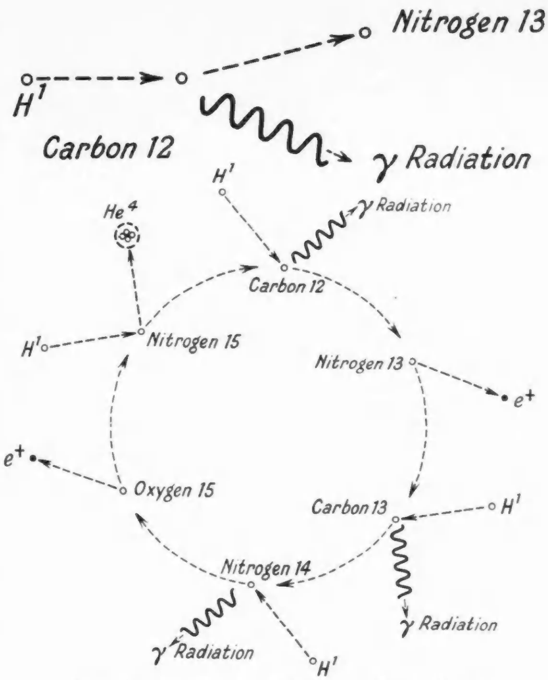
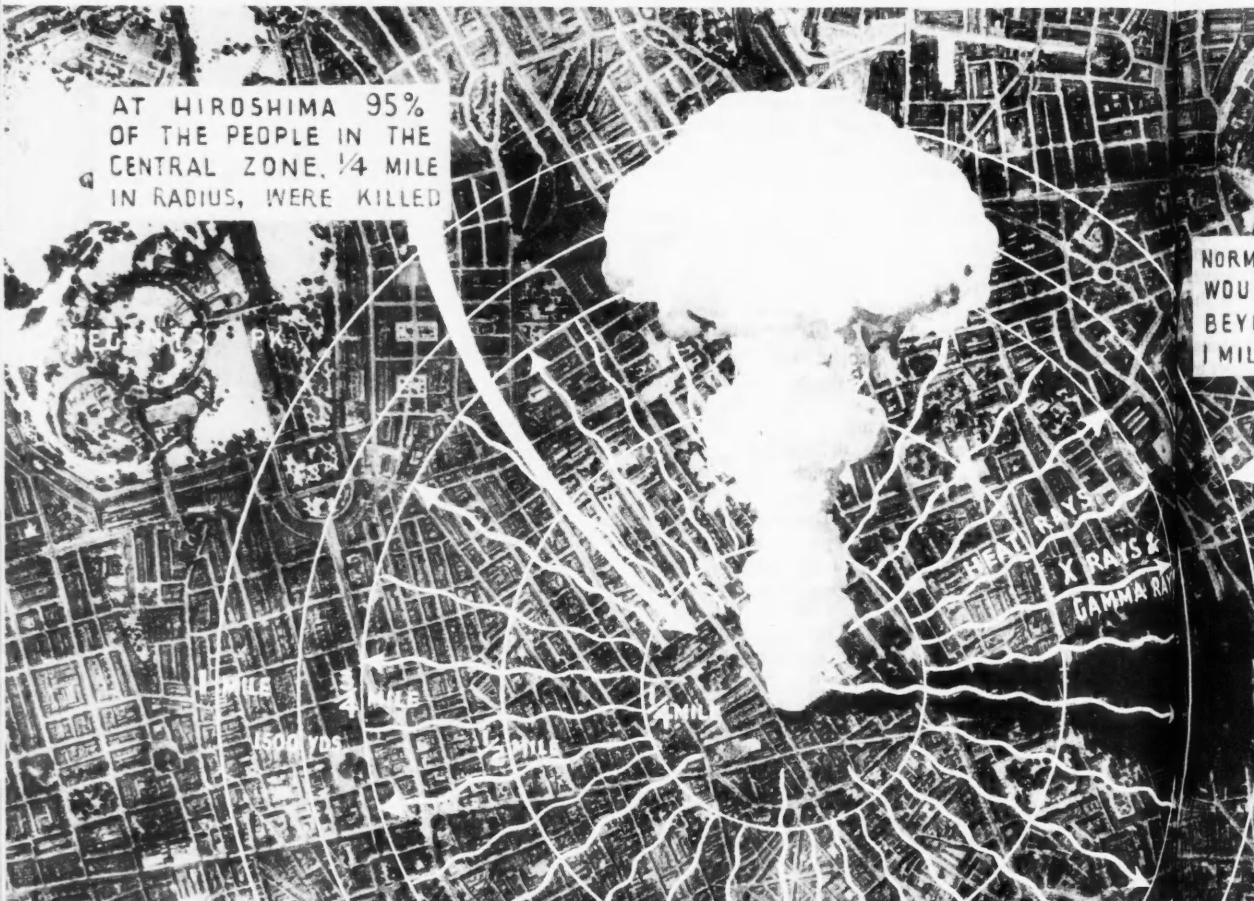
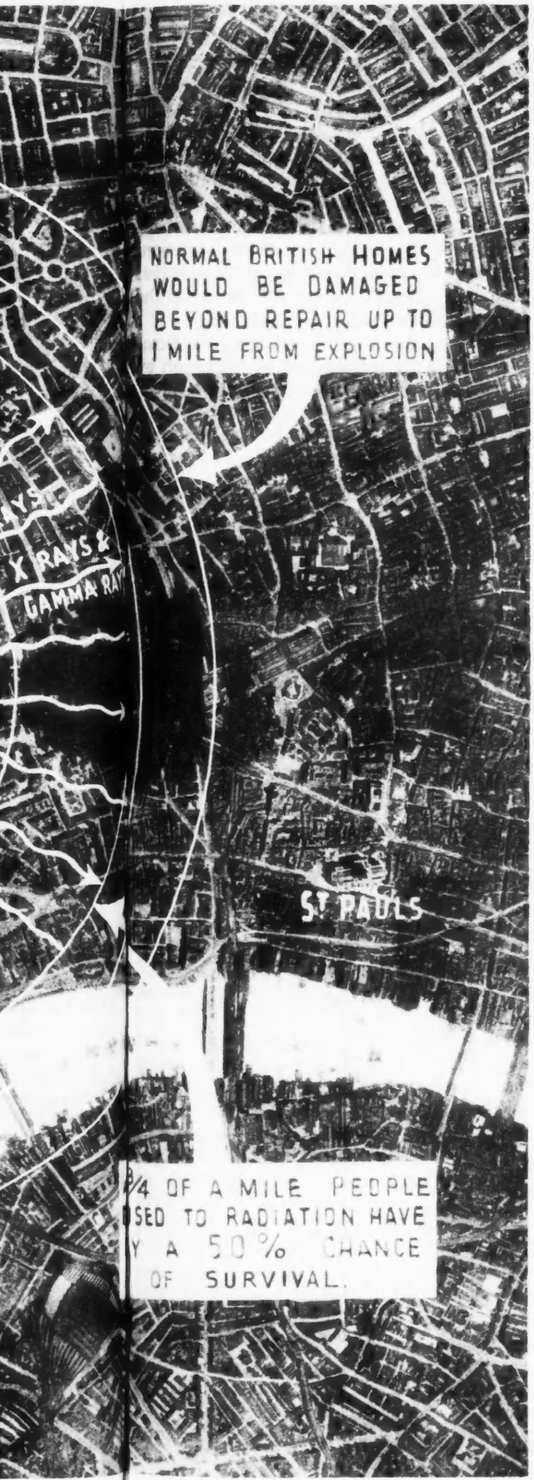


FIG. 29.—THE ENERGY PRODUCTION CYCLE IN THE SUN. If a hydrogen nucleus (H^1) collides with a carbon nucleus the former is captured, and short-wave gamma radiation (very short X-rays) is emitted. This reaction is illustrated in the upper diagram. In the whole cycle of interactions which are responsible for the production of stellar energy, a series of interactions shown in the lower diagram takes place. The carbon nucleus takes up four hydrogen nuclei in turn, the consequent secondary changes leading to the emission of two positive electrons (positrons, denoted by e^+) and three gamma rays. The final nucleus splits up to give a helium nucleus (He^4) and the original carbon nucleus. The latter thus acts as a carrier or catalyst in the conversion of hydrogen into helium.

gas so that the walls themselves form part of the experiment and soon re-endow a particle which has been slowed down, with a new supply of energy.

The loss of mass involved in the conversion of hydrogen into helium is small, but in the case of the sun it corresponds to the loss of about 4 million tons of mass every second, corresponding to the conversion of about 570 million tons of hydrogen into about 566 million tons of helium. As fuel the sun has one third of its mass composed of hydrogen, and less than 1% of this would be lost if it were all converted into helium. At first sight it seems that even this process would be insufficient to keep the sun going, since it might be thought that a loss of 4 million tons per second would soon write off the mass amounting to one-third of 1% of the mass of the sun, which is available for conversion. However, a simple calculation shows immediately that, assuming the present rate of conversion, the sun will be able to go on radiating for another 30,000 million years, which is quite adequate to comply with the observed time scale.


AT HIROSHIMA 95% OF THE PEOPLE IN THE CENTRAL ZONE, 1/4 MILE IN RADIUS, WERE KILLED
HEAT RAYS
X RAYS &
1 MILE
1500 YDS
EXPOSED SKIN IS SEVERELY BURNT UP TO 1500 YARDS FROM CENTRE OF EXPLOSION.
IN THIS ZONE NEARLY EVERYONE EXPOSED TO GAMMA RADIATION DIES.



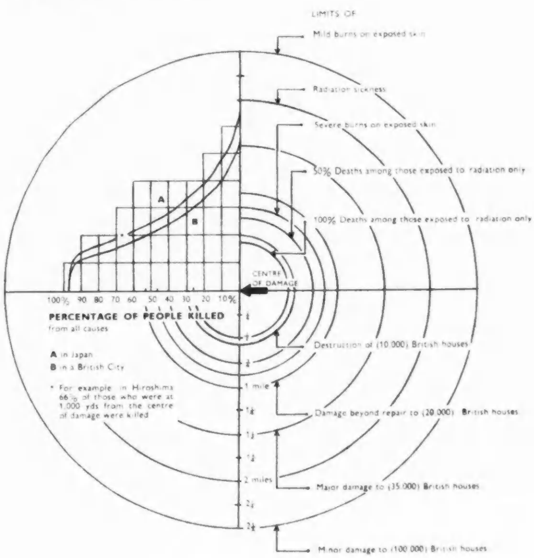
The lesson of Hiroshima and Nagasaki

WHETHER the Bikini tests show that navies as we know them are obsolete or not is of small account to the inhabitants of big cities against whom atomic bombs would primarily be aimed if ever war broke out again. The results of these tests cannot serve to underline the necessity for strong international control of atomic energy as sharply as do the recent British and American reports on Hiroshima and Nagasaki. In the absence of that control metropolitan man becomes obsolete and, with him, modern civilisation.

There is no room here to summarise the details of the report which the British mission prepared on *The Effects of the Atomic Bombs at Hiroshima and Nagasaki* (Stationery Office, 1*s*.) or of the U.S. Strategic Bombing Survey Report on Atomic Bombing in Japan. These reports are available to the public and need to be read by everybody.

Some of the salient facts collected by the British mission have been transferred to the aerial map of London reproduced alongside. A bomb is imagined to have burst over Bloomsbury. This can bring home more vividly than mere words the lesson of Hiroshima and Nagasaki. The data on which this illustration is based was taken from the British report. No place on the photograph, let it be noted, would be safe from the point of view of radiation sickness with all its attendant horrors. The scale of atomic death and destruction is shown in more detail in the diagram below, also taken from the report.

The bombs that burst over the Japanese cities are already out of date.



Time and the Biologist

Professor F. E. ZEUNER, D.Sc.

In the classic days when the Theory of Evolution was being crystallised workers showed a considerable interest in the chronological aspects of the processes involved. Naturally, they were hampered by lack of time-scales of a reliable character and were therefore compelled to fall back upon more or less fanciful guesses. Nevertheless, for the greater part of the nineteenth century the importance of the time-factor in evolution was clearly realised.

As long ago as 1809, Lamarck, in this famous *Philosophie zoologique*, considered the time required for evolutionary changes. He had no chronology based on scientific methods, though his guess that thousands and millions of centuries are the measures of evolution is borne out by the results of the modern radioactivity methods. Charles Darwin was fully conscious of the importance of the time-factor in evolution and devoted about twenty pages of his *Origin of Species* to it. Alfred Russell Wallace's famous book, *Island Life*, contains a whole chapter on this problem.

In the eighties of the last century, however, the time of Weismann's *Theory of the Continuity of the Germ Plasm*, the chronological aspect of evolution began to drop out of sight, at any rate in those branches of biology which occupied themselves with microscopical anatomy and with experimental work. Morphologists, palaeontologists and taxonomists, many of whom still regarded Lamarck's conception of the inheritability of acquired characters with some favour, continued for a while to refer to the time-factor in evolution as did, for instance, Theodor Eimer of Zurich in 1890. Even Weismann himself was fully aware that evolutionary processes might look rather different from what he himself considered them to be like if only long periods of time were taken into account. Unfortunately, Weismann said that Egyptian mummies showed that mammals including man had not changed their characters in the last 4000 years and that *therefore* the time-factor might be disregarded. This was in 1886, and it did not take long for this view to be accepted almost universally. In the light of geochronology, of course, the 4000 years on which Weismann relied appear hopelessly inadequate. The great biologist himself, it should be appreciated, did no more than restrict his field of work to a short portion of the time-scale, and he cannot be blamed for doing so. It was only his followers who, immersed in experimental work, forgot that nature had more time at her disposal for processes of evolution than have biologists for their experiments. But the upshot was that for many years, the time-factor practically vanished from discussions on evolution. If ever it was brought up by palaeontologists or taxonomists, it was liable to be turned down on the strength of Weismann's argument.

In the eyes of the vast majority of biologists the time-factor was finally ousted from the arena of evolution by the concept of the *generation*, which, in addition to its original meaning, of a step in the pedigree covered by one individual from its birth to the birth of its offspring, acquired a chronological significance. Of course, a generation covers a varying period of time, but this, in spite of its varying length, was by many workers regarded as an adequate time unit for all kinds of evolutionary research. Thus, M. Hartmann, the geneticist, said in 1928 at a joint conference of geneticists and palaeontologists that

TIME SCALE million years				
	MAMMALS	MAN	HOMO: MODERN MAN	Pleistocene
	MAMMALS	MAN	HOMO: NEANDERTHAL MAN	Pleistocene
1/4	MAMMALS	MAN	HOMO: SWANSCOMBE MAN	Pleistocene
1/2	MAMMALS	MAN	HOMO: PILTDOWN MAN, PITHECANTHROPUS	Pleistocene
	MAMMALS	APES	Stage represented by AUSTRALOPITHECUS	? Pliocene, S. Africa
15	MAMMALS	APES	DRYOPITHECUS (higher anthropoid ape)	Upper Miocene
	MAMMALS	APES	PROPLIOPITHECUS (primitive simiid)	Lower Oligocene, Egypt
35-40	MAMMALS	MONKEYS	PARAPITHECUS (Catarrhine monkey)	Lower Oligocene, Egypt
60	MAMMALS	LEMURS	ANAPTOMORPHIDAE (primitive tarsioids)	Palaeocene
	MAMMALS	INSECTIVORS	PRIMITIVE TUPAIIDS (tree-shrews)	
80	MAMMALS	INSECTIVORS	ZALAMBDALESTES (Insectivors related to hedgehog)	Upper Cretaceous, Mongolia
	MAMMALS		DELTATHERIDIUM (earliest placentalian mammals)	Upper Cretaceous, Mongolia
120	MAMMALS		PANTOTHERIA (pre-placentalian mammals)	Middle-Upper Jurassic
170		MAMMAL-LIKE REPTILES	'ICTIDOSAURIA' (transitional between reptiles and mammals)	Triassic
190		MAMMAL-LIKE REPTILES	THERAPSIDA	Middle Triassic
230		MAMMAL-LIKE REPTILES	PELYCOSAURIA	Upper Carboniferous
260			AMPHIBIA	Lower Carboniferous
290		FISH-LIKE FORMS	CROSSOPTERYGIAN FISHES	Devonian
320		FISH-LIKE FORMS	PRIMITIVE PLACODERMS	Silurian
370		FISH-LIKE FORMS	AGNATHA (jaw-less fishes)	Ordovician
		FISH-LIKE FORMS	AMPHIOXUS STAGE	
?		INVERTEBRATES	PRE-ECHINODERM STAGE	No fossil record. These hypothetical stages derive from results of embryological research.
		INVERTEBRATES	COELENTERATES	
		INVERTEBRATES	PROTOZOA	

Table showing tentative pedigree of Man; the time-scale is very approximate. The views incorporated in this table are those prevailing at the moment; they are, of course, liable to be modified as research proceeds.

4000-5000 generations of amoebae represented, *by reason of their shortness*, an immense period of time, and that therefore absolute time was altogether 'rather unimportant' in the study of evolution.

This virtual identification of the *generation* with *absolute time* is, however, open to criticism as will be seen later. So long as reasonably reliable time-scales for the past were non-existent this identification had its advantages, but it is now worth while to re-examine it in the light of the chronologies which the radioactivity, astronomical and varve methods (described in my article in the April issue of DISCOVERY) have placed at our disposal.

It must be admitted that the fading out of the time-aspects in research on evolution was closely connected with the absence of dependable absolute time-scales. The astronomical time-scale put forward by the astronomer, James Croll, in 1864, to which A. R. Wallace paid much attention, had been shown to be erroneous, and the radioactivity method did not begin to bear fruit until the second decade of the present century. The varve method and the modern version of the astronomical method also date from about the same time.

Now that these methods have provided us with some time-scales which, though rough, imperfect and inaccurate in many respects, at least give an idea of the right order of magnitude of the periods of time concerned, it is worth while to see what light chronology may be able to shed on the processes of evolution.

The most immediate application to which the time-scales can be put in biology is the dating of stages of phylogenetic lines with their ramifications, or as they are usually called, trees. Though this use is obvious, it has occurred to but a small number of scientists to do so, and to a still smaller number to study some of the implications of such 'dated' pedigrees. Professor J. B. S. Haldane was among the first to realise the applicability of absolute time-scales to evolution. Nearly twenty years ago, in his book *Possible Worlds* a chapter is to be found wholly concerned with dates in evolution. "60,000,000 years ago our ancestors were mammals, probably not unlike lemurs, 300,000,000 years ago amphibians somewhat resembling newts or mud-puppies, and 500,000,000 years ago very primitive fish, combining some of the characters of sharks and lampreys." In the table opposite, man's pedigree is elaborated, and some modern views incorporated. It must not be regarded as the final word, yet in its broad outline it is unlikely to be far off the mark; a time-scale has been added, most of it arrived at by the use of the radioactivity method; only for the Pleistocene was the astronomical method used. This time-scale enhances the interest of the pedigree and may cause the student to raise questions concerning the time-rate of evolution, such as: How much time did it take for a new species to evolve? How long may species persist unchanged? How long do families or higher groups survive? It prompts one to ask whether new lines are apt to split off at any time or whether there are periods of intense splitting of a group into new forms, and other periods when splitting occurred but rarely.

In the table the phylogenesis of man has been taken as an example and, for the sake of simplification, side-branches have been left out. Phylogenetic diagrams of other groups and others showing the branches into which a group split in the course of time may of course be constructed and

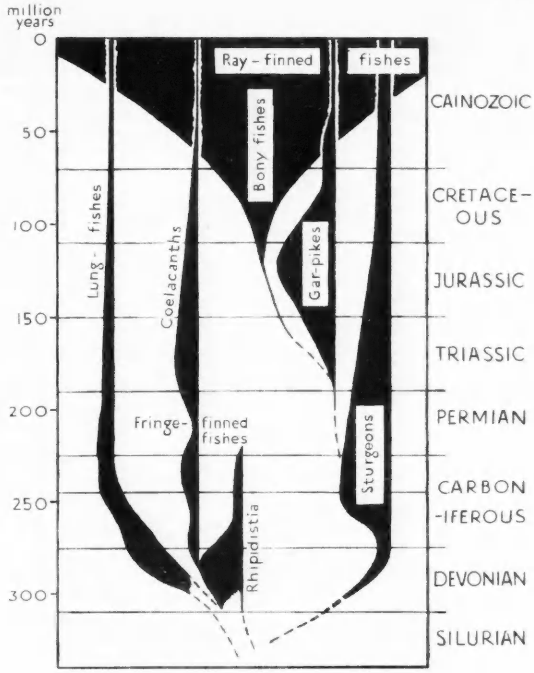


FIG. 1.—The evolution of the true fishes, with time-scale on the left. The thickness of the branches indicates the relative abundance of the members of the various groups. The Lung Fishes (*Dipnoi*) and Fringe-finned Fishes (*Crossopterygii*) probably had a common origin. The other major groups are: Ray-finned Fishes (*Actinopterygii*), to which most modern fishes belong; the Sturgeons (*Chondrostei*) are the oldest sub-division; the Gar-pikes and Bow-fins (*Holostei*) the second, and the Bony Fishes (*Teleostei*) the third. The Bony Fishes increased enormously in the Cretaceous and Tertiary times; it is not impossible that they reached their climax in the late Tertiary. (Based on a diagram by Prof. A. S. Romer of Harvard, with modifications.)

either supplied with dates, or plotted on the time-scale, duly considering the varying durations of geological periods. Such plots and tables have been used occasionally in palaeontological books; as an example, a pedigree of the major groups of fishes is shown in our Fig. 1, adapted from Professor Romer's Textbook of Palaeontology.

If one considers a number of reasonably well established lines of descent relative to the absolute time-scale, it will be noticed that the rate of change per time-unit is great in some and small in others. From studies carried out by Dr. R. A. Stirton of the University of California, Dr. G. G. Simpson calculated that the ancestral line of the horses (Fig. 2, overleaf) changed at such a rate that on the average a new genus evolved within $5\frac{1}{2}$ million years. But for Triassic and earlier ammonites, relying mainly on the work of Professor H. H. Swinnerton of Nottingham University, Simpson found that a line required about 20 million years to change from one genus into a new one. There are other lines of descent which have never changed sufficiently to be regarded as having passed the limits of the original genus. The best known example of this kind is the brachiopod called *Lingula* (Figs. 3-5), a genus which appeared

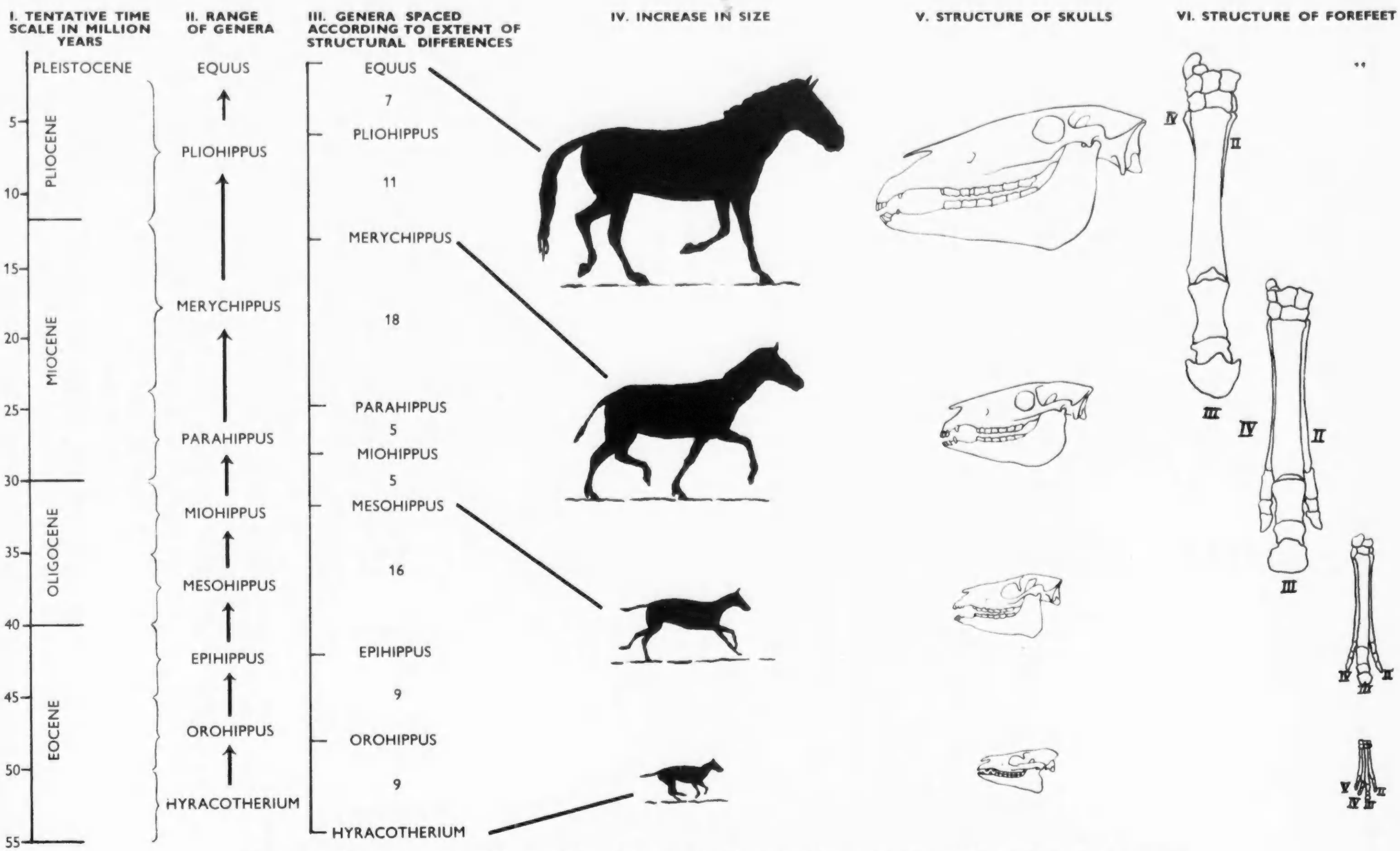
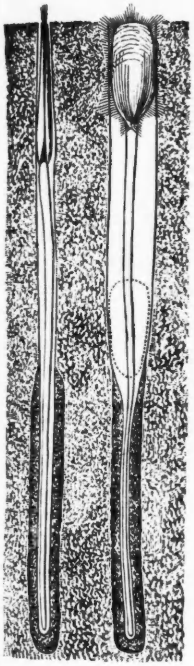
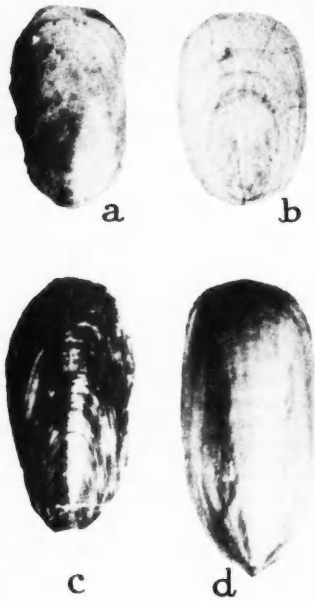


FIG. 2.—THE EVOLUTION OF THE HORSE. Column I gives a tentative time-scale covering the period of evolution of the modern horse, *Equus*, from the ancestral genus, *Hyracotherium*. II. The range in time of the horse's ancestors (according to Dr. R. A. Stirton). III. Here the horse's ancestors are spaced in accordance with the amount of structural modification between successive stages; the figures indicate this amount measured in arbitrary units. Note that the step from *Epihippus* to *Mesohippus* was great, though it did not take more time than the preceding one from *Orohippus* to *Epihippus*. Evolution appears to have been accelerated in this case, as also from *Parahippus* to *Merychippus*. The rest of the diagram indicates the trend of evolution in respect of size, skull form and structure of the fore-feet. Note, for instance, the closing of the orbit; and the reduction of the number of toes until it comes to the modern horse with its single hoofed toe. The duration of the Tertiary is assumed to be 70 million years; some authors assign only 60 million to it. (***Based on work of E. D. Cope, W. B. Scott, W. D. Matthew, G. G. Simpson, C. E. Knight and others.***)





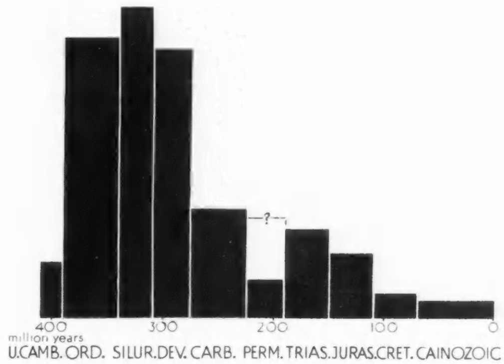


FIG. 3 (*left*).—The habit of the brachiopod, *Lingula*. The shell has two valves. With its long worm-like pedicle or stalk, it burrows in mud; microscopic food particles are brought to the mouth by the current of water set up by cilia. (*After Francois.*)

FIG. 4 (*centre*).—The brachiopod genus known as *Lingula*, of which four species are shown here, has persisted from the Upper Cambrian to the present day. These brachiopods burrow in marine mud; such an environment would have remained more or less constant over long periods and once adapted to this environment the genus appears to have had no cause to undergo any major modification. Species have died out and others have appeared but the genetic type has not altered as is shown by these specimens of (*A*) *Lingula symondsi* from the Silurian of Buildwas, Shropshire: (*B*) *L. squamiformis* from the Lower Carboniferous, Campsie, Stirling; (*C*) *L. truncata* from the Lower Greensand, Hythe, Kent; (*D*) *Lingula anatina*, living species from the Phillipines. (*These photographs, twice natural size, are from specimens in the Natural History Museum.*)

FIG. 5 (*right*).—Diagram showing the frequency of species of *Lingula* in various geological periods. For each geological period the area of the column is proportional to the number of species known. Note the sudden rise in the Ordovician; the 'explosive phase' lasted about 70 million years. After the Devonian the decline was at first sudden, then became gradual. The small number of species recorded from the Permian is to be regarded as due to circumstances of preservation. (*Based on catalogue of* 438 *species compiled by the author with the assistance of Dr. H. Muir-Wood of the Natural History Museum.*)

late in the Cambrian and has survived to the present day. Its rate of generic change, therefore, must be very small indeed, the genus having persisted for something like 400 million years. It is evident, therefore, that some genera change so slowly that they may be regarded as almost stable, the only changes occurring in the characters of the species. Other genera, however, have become extinct by evolving into new genera at rates which mean that the line would have passed through several genera within a single geological period.

Rate of Species Evolution

One may be inclined to interpret these different rates of generic evolution in terms of 'species-steps'* assuming that each lineage would pass through several evolutionary changes which each result in a new species, before the differences have accumulated sufficiently to justify calling the descendants a 'new genus'. In this connexion it is of great interest to know how much time is required under natural conditions for the evolution of a new species. It has been possible to tackle this question in a number of groups with a fossil record sufficiently complete to establish (with fair degree of probability) direct lines of descent. But in these cases the periods of time involved are to be measured in thousands of years instead of millions. Most examples, therefore, come from the latest geological periods—the late Tertiary, the Pleistocene and the Post-glacial.

* This is a convenient term denoting the amount of evolutionary change which a lineage undergoes in the course of time. When the differences between the ancestral form and the descendant form have become sufficiently great to justify calling the latter a new species, the lineage may be regarded as having advanced by one 'species-step'.

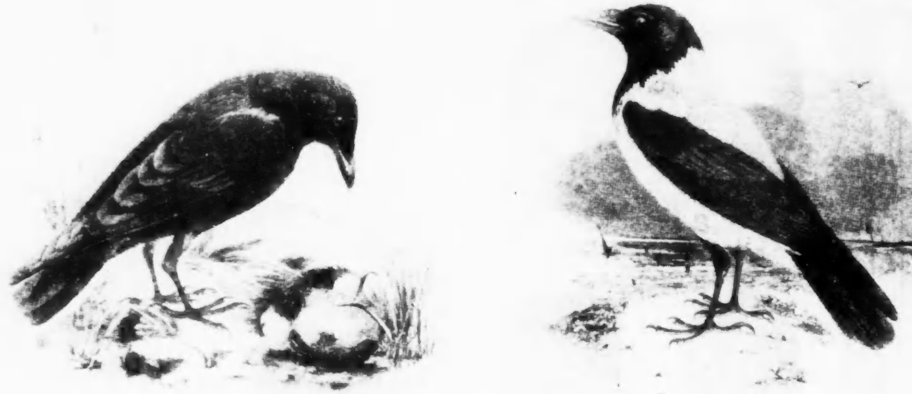


FIG. 6.—The Carrion Crow (*left*) and the Hooded Crow (*right*) are two very closely related species which are regarded as the products of geographical isolation. The Pleistocene ice-sheets appear to have divided the area of distribution of their common ancestor into a south-western 'refuge' area where the Carrion Crow evolved, and a south-eastern one where the Hooded Crow evolved. Now the two species meet along a line that stretches from the Alps north to Jutland and across the North Sea to Scotland. The two species are still capable of interbreeding. This incomplete differentiation of two descendant species is the result of half a million years of evolution. (*From Yarrell's "British Birds".*)

The time which has passed since the end of the Last Glaciation is about 10,000-20,000 years according to the part of Europe under consideration. During this period no new species are known to have evolved,* but some forms become sufficiently distinct to be classified as *subspecies*. As examples, the British Red Deer and the Large Copper Butterfly may be mentioned. In both, differentiation from the races of the continent of Europe is apparently the result of geographical isolation since the submergence of the English Channel (about 8000-9000 years ago), though isolation may well have been practically complete at a somewhat earlier date. The differences of the British races from the Continental ones are still very slight and apparently not yet fixed genetically. British Red Deer imported into New Zealand developed into specimens resembling Continental races, and the variation of the British Large Copper overlaps considerably that of the Dutch race. It will be interesting to see whether Dutch Coppers which have been released in this country will develop the characters of the British race, which incidentally has been extinct for nearly a hundred years. Experiments are at present in progress.

This and other evidence suggests that 10,000 years suffice for the evolution of genetically unfixed subspecies or one might better say geographical races. Several workers have come to similar results, among them Dr. Julian Huxley.

In order to find greater differences between subspecies, such as differences in the bony parts of mammals, one has to go back to the Upper and Middle Pleistocene. Many species which then existed have survived to the present day almost without change, but some show fairly marked differences, as for instance the marmots and ibexes in their skulls. Subspecific differences of this kind found in material which has been dated by means of the astronomical method suggest that major subspecies need between 100 and 250 thousand years to evolve. Unfortunately, our knowledge of middle Pleistocene faunas is still somewhat scanty.

* The following considerations do not apply to the plant kingdom.

This disadvantage is far outweighed by the large number of early Pleistocene faunas, many of which are well studied. Their absolute age is about half a million years. As an example, the mammalian fauna of the 'Forest Bed' deposits from Cromer, Norfolk, may be mentioned. They are of First Interglacial age. In this fauna, only 14% of the species are identical with Recent ones, the remaining 86% being forms that have since become extinct and subspecies and species different from, but ancestral to, Recent forms. In half a million years, therefore, some mammals have changed sufficiently to be called different species, though others have evolved at slower rates. 500,000 years then appears to be something like a maximum rate for the evolution of species of mammalia under natural conditions. It applies to several unrelated groups like elephants, rhinoceros, bears, voles, deer and others. There are many, however, which show a slower rate than this.

Turning to marine faunas, one finds that in the same half million years there has been much less specific change. The shells from the marine coastal deposits known as the East Anglian 'Crags' contain as many as 80% of Recent forms. Evolution of species in marine mollusca (and other groups) thus appears to have been on the whole slower than in the terrestrial mammals.

This raises the question how long species have remained unaltered, in other words how *slow* species evolution can be. It is difficult to answer if direct lines of descent are considered, since very few of them have been traced through long periods of time. But statistical analysis of marine mollusca shows that while Miocene faunas may still contain some 10% of Recent forms, Oligocene and Eocene†

† The subdivisions of the Cainozoic are as follows:

Quaternary		Holocene (Postglacial)
		Pleistocene (Ice-age)
Tertiary	Neogene	Pliocene
		Miocene
	Palaeogene	Oligocene
		Eocene
		Paleocene

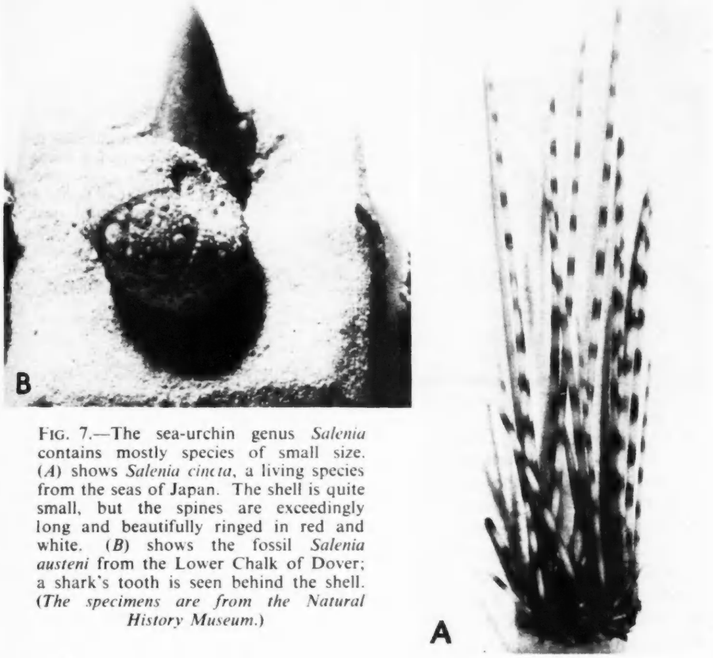


FIG. 7.—The sea-urchin genus *Salenia* contains mostly species of small size. (*A*) shows *Salenia cincta*, a living species from the seas of Japan. The shell is quite small, but the spines are exceedingly long and beautifully ringed in red and white. (*B*) shows the fossil *Salenia austeni* from the Lower Chalk of Dover; a shark's tooth is seen behind the shell. (*The specimens are from the Natural History Museum.*)

FIG. 8.—Diagram of the sea-urchin *Salenia*, showing the frequency of species in relation to time. Note the steep rise in the Cretaceous indicating intense splitting into new species for a period of about 40 million years; this is followed by an almost catastrophic drop at the end of the Cretaceous. Today only four species exist. (This diagram, based on 76 species, is from *Dating the Past*.)

faunas do not contain any. This gives us a bracket suggesting that at least some recent species are as much as 30 million years old.

The application of geochronology to species evolution thus leads to the tentative conclusion that 500,000 years is a very fast rate, and possibly a maximum, whilst the slowest rates are in the neighbourhood of 30,000,000 years. These figures may well have to be modified as research proceeds, but evidence at present available suggests that the fast rate is likely to be exceeded in exceptional cases only.

Rate of 'Splitting'

So far we have been considering the changes which occur between ancestral and descendant forms along a direct line of descent and we have disregarded the fact that at frequent intervals species split into two or more new forms which in due course become new species. This branching of the lineages is a normal and general process, without which few groups would survive in the long run, since many species die out in the course of time owing to the action of internal (genetic) and external (environmental) factors. If the rate of extinction of species in a genus is equal to the rate of splitting, the number of species in the genus will remain constant, though the species themselves change. If the rate of extinction is greater than the rate of splitting, the number of species in the genus will more or less gradually diminish to the point of extinction of the genus. But if in a genus the rate of splitting is greater than the rate of extinction, the number of species existing will rise, the rise becoming increasingly steeper as time goes on (and provided the rate of extinction remains constant). The steepness of the rise is easy to understand. Suppose, for instance, that at the beginning the genus contained two species. Let the rate of splitting be once per million years, and the rate of extinction one species per million years. Then, at the end of the first million years the two initial species will each have split into two, making four in all, of which, however, one will have become extinct. This leaves a balance of three. This process, if continued for 5 million years, will result in the presence of 33 species, the number being nearly doubled every further million years.

Explosive Evolution

We are not here concerned with the causes that determine the rates of splitting and extinction, but with the fluctuations in the number of species in relation to absolute time. These are best shown in diagrams, like Fig. 5. It is of course of little use to construct diagrams for groups whose fossil record is very incomplete such as the worms, the preservation of which is possible only under exceptional conditions. But there are many groups with a reasonably satisfactory fossil record and many of these show that a genus (or family) passed at some time through a *phase of intensive splitting* of the species.

As an example of such a phase of great intensity, the sea-urchin genus *Salenia* is shown here (Figs. 7-8). In this

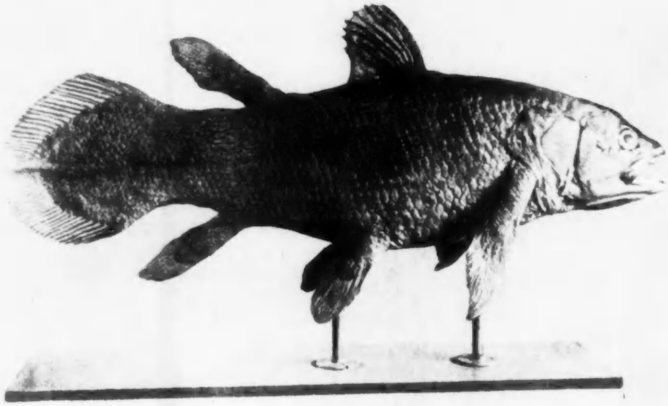


FIG. 9.—It was a great surprise to the scientific world when a living Coelacanth, *Latimeria chalumnae*, was caught in a trawl at 40 fathoms off the South African coast near East London in December 1938. The fish is five feet in length. (*Photograph taken from a cast in the South African Museum.*)

particular case, the rapid rise of the number of species to its climax in the late Cretaceous was followed by a catastrophic drop. In other cases, e.g. the Coelacanth fishes, the climax is less pronounced, and the drop moderate. (Figs. 9-10.) The more usual type is exemplified by the snail genus, *Poiretia*. (Fig. 13.)

This rapid rise in the number of species is a phenomenon with which palaeontologists have long been familiar, though its chronological aspects have not been studied until recently. By some it is called *explosive evolution*.

Now, if one measures the duration of the phase of rapid increase (which is usually preceded by an initial *lag phase*) one notices that it is limited to a few tens of millions of years. *Salenia* (Fig. 8) and *Poiretia* (Fig. 13) are good examples. One might object that 'conservative' genera, such as the brachiopod *Lingula* would have a longer phase of increase, but this is not so, as is seen in Fig. 5. Thus is appears that in many genera the phase of intense species-splitting is limited in time, lasting on a broad average something like 50 million years. It will be interesting to see whether future research will enable us to generalise these observations, so that this limitation can be regarded as a rule.

The diagrams, Figs. 5, 8 and 13 show the numbers of species within a particular genus. In a similar manner the number of genera in a family (Fig. 12) or families in an order, or even orders in a class can be plotted against the time-scale. One might then expect to find that any 'explosive' phases which might become apparent would have lasted the longer the higher the systematic rank considered. Thus, an explosive phase might have lasted longer in an order than in a family, in a family longer than in a genus. Surprisingly, this is not so. 'Explosive' phases are indeed observed, for instance, in the production of new genera in a family but, in all examples so far investigated, the duration of the explosive phase is not longer for genera in a family, or even orders in a class, than for species in a genus, i.e. again it is of the order of 50 million years.

It has not been possible yet to investigate many cases of this type, and further evidence is required. That available at the present has been drawn from mammals, fishes, insects, echinoderms, brachiopods, molluscs and Foraminifera; it appears to indicate that the duration of 'explosive' episodes is independent of the systematic level at which it occurs.

The significance of this apparent limitation of the duration of explosive phase is still obscure. That the length of the period is similar in low and high systematic categories may perhaps mean that the number of species-steps involved in the evolution of a new family or order is not greater than that involved in the evolution of new genera.

In that case, the difference must lie in the quality of the steps, not in their quantity, a suggestion which has been deduced before, from purely morphological evidence, by the Russian vertebrate zoologist, A. N. Sewertzoff. More recently, the significance of qualitative differences in evolutionary steps has come to be recognised in the genetic field also, as for instance in the book on the Material Basis of Evolution by Professor R. Goldschmidt of the University of California.

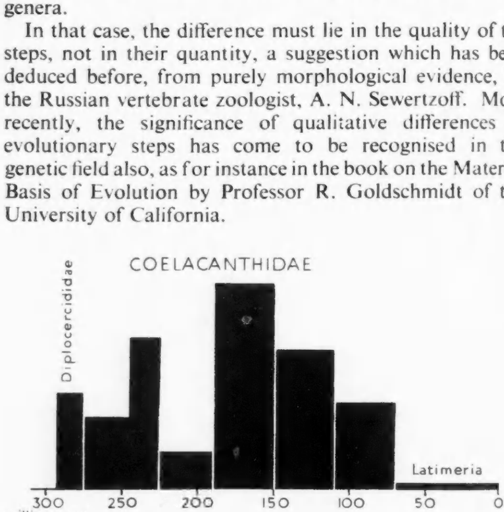
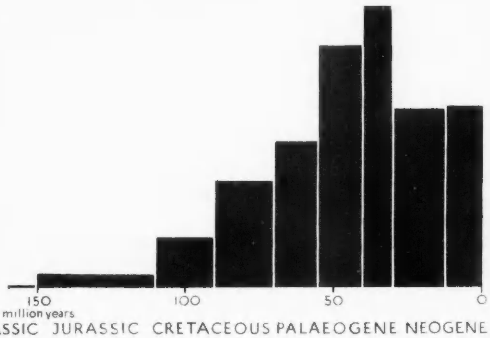


FIG. 10.—Diagram showing frequency of species of Coelacanth species in relation to time. In the Upper Devonian the family Diplocercididae flourished. In the Carboniferous it was replaced by the Coelacanthidae which reached their climax in the Triassic. The small number of Coelacanths recorded from the Permian may not represent their true frequency owing to the fact that relatively few marine deposits are known from the Permian. Possibly, therefore, the rise to the climax in the Triassic was not interrupted in the Permian, as is shown in the diagram, but was continuous from the Lower Carboniferous; if so, the rise would have taken about 100 million years and the rate of evolution would then be one of the slowest known. The Coelacanths are regarded as a very conservative group which changed but little in the course of time. (*Based on 62 species, material supplied by Dr. Errol I. White, of the Natural History Museum.*)



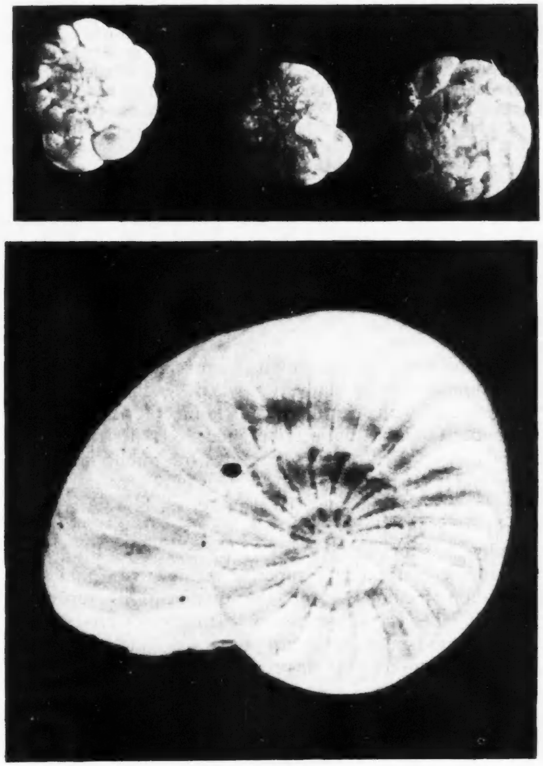


FIG. 11 (*right*.)—Two examples of Rotaliid foraminifera. *Rotalia beccarii* (*top*), a living species, showing ventral and dorsal surfaces, and the spiral arrangement of the chambers of the shell which is typical of this super-family. (*Below*) The fossil *Operculina complanata*: this is a conservative species which has existed since the Eocene. (*Natural History Museum specimens*.)

FIG. 12 (*above*).—Diagram showing the frequency of genera in the super-family Rotaliidea in relation to time. The surface area of each column corresponds to the number of genera present in the particular period. After an initial 'lag phase' lasting from the late Triassic through the Jurassic, the group experienced a phase in which many new genera were produced and this lasted for about 70 million years. After the climax in Mid-Tertiary times, some genera died out and comparative stability was achieved. (*Based on 86 genera. Compiled from various sources with the assistance of Mr. C. D. Ovey, of the Natural History Museum*.)

The theory of genetic mutation tends to support the widely held belief (referred to earlier in this article) that a fast succession of generations results in rapid evolution of the species or group under consideration. This, however, is not supported by palaeontological evidence viewed in the light of geochronology. The time-rates of evolution, measured in species-steps, may differ, but there is no correlation of fast rates with groups having a rapid succession of generations. Actually the fastest rates of species evolution are exemplified by mammals such as the elephants, which have generations of at least six years (this is known from breeding experiments in zoological gardens; the figure is probably more under natural conditions) whilst the famous fly genus *Drosophila* is at least 50 million years old, in spite of its generations of only a few weeks. Even Protozoa, such as the Foraminifera, have proved to be remarkably persistent types. It appears, therefore, that in nature the number of generations is not the only factor ruling the rate of change, and that the latter is somehow related to absolute time. This was pointed out by the present writer more than fifteen years ago, and recently Dr. G. G. Simpson has independently made the same observation. It may be well worth while to pay closer attention to this curious matter. Possibly, as Professor J. B. S. Haldane has pointed out to me, differences in the mutation rates may account for it, but very few mutation rates are known so far. They are bound to vary a good deal. Dr. Simpson is inclined to think that most evolutionary lines are consistent with moderate mutation rates and that

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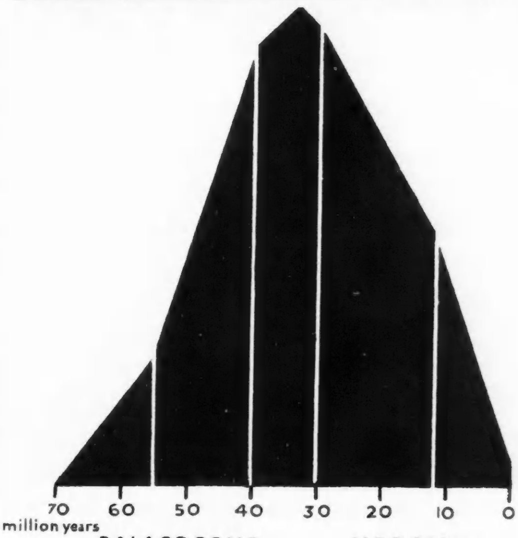

FIG. 13.—Diagram showing the number of new species of the molluscan genus *Poiretia* appearing in the different sub-divisions of the Tertiary. The maximum output of new species was attained in the late Palaeogene, within 30-40 million years of the appearance of the genus. (*Based on 54 species*.)

FOR over eighty years scientists have known how to grow plants without soil, but it is only recently that soilless cultivation has become practicable even on greenhouse scale. High claims have been made for the method. We are told, for instance, that the yield-per-acre of crops like potatoes can be boosted by six to ten times. In America it has been studied by agricultural stations and developed to the stage where it is effective under greenhouse conditions, and it has been taken up enthusiastically by commercial growers—and over-enthusiastically by amateurs. In Britain the climate does not seem to favour water-culture methods, and here attention has been directed to the sand- or gravel-culture method. Whether soilless culture can ever become a competitor to agriculture has yet to be seen, but that it is likely to find use in those parts of the world where the soil is infertile is indicated by successful experiments made on Ascension Island and Iwojima by the U.S. Army.

Crops without Soil

D. P. HOPKINS, B.Sc., F.R.I.C.

AT a time when the newspapers are crediting chemists with miracles almost daily, yet when headlines in other columns deal with such matters as famine and starvation, it is understandable that every popular reference to soilless cultivation or 'hydroponics' captures the public imagination. Here, it would seem, is a new way of creating food, an extra production line. Two questions, however, must be raised even when famine stalks the world. Is there actually a shortage of soil? Alternatively, does the hydroponic method give superior results to normal soil cultivation methods? And the qualification 'superior' must take into account the economic factor of production cost; for food must be 'cheap', or at any rate within the purchasing powers of poor people as well as rich.

A plant's own food needs are derived (*a*) from the atmosphere and (*b*) from the soil. A great deal of a plant's structure is, indeed, built up from carbon, oxygen and water, all derived via carbon dioxide, air and rain. The soil's particular contribution is to provide (usually with fertiliser or manure help) such nutrients as nitrogen, phosphorus, potassium, calcium, magnesium, boron, manganese, sulphur, and so on. Humus is needed in the sense that it is a 'food' for the soil, a material which will in many ways maintain the various fertility processes that must occur in the soil before plants can draw efficiently and steadily upon the soil's contents. If we eliminate the soil as a medium for nutrient-handling, then we also eliminate the humus requirement. A dilute aqueous solution of the nutrients normally supplied by or via the soil can replace the soil. Nor is there anything new or revolutionary in this. In agricultural laboratories 'water culture' and 'sand culture' have been used as methods of investigation since about 1860; by such methods Liebig's main principles of mineral or chemical nutrition were studied in detail, and the relative importances of this or that element were evaluated. But there is perhaps more than a touch of the 'ivory tower' attitude in the fact that the first attempts to adopt these laboratory methods for actual crop-production were made only as recently as 1929 by Dr. W. F. Gericke, an American scientist. To the historical fact there should be added a geographical fact —Dr. Gericke carried out his work in California. As will be seen later, this has had a considerable bearing upon the recorded progress of hydroponic or soilless cultivation.

There is some controversy concerning the use of the somewhat cumbersome word, 'hydroponics'. Pioneers in the field claim that only one of the several systems of soilless cropping is actually hydroponic; unfortunately the different authorities claim this honour for different systems. The all-embracing title of 'soilless cultivation', therefore, is less likely to distress expert sensitivities.

Dr. Gericke's successes have been mainly achieved by working with nutrient solution reservoirs. Above the solution level—but leaving a space for air—a porous mat of some kind of vegetable litter acts both as a seed-bed and a physical support for the plants. The plants' roots hang down into the solution. Lest the organic-minded should assume from this brief account that the vegetable litter itself contributes to plant-growth, it should be added that, although such materials as peat or leaf mould are very serviceable as litter components because they are easily obtainable and are efficiently porous, much more inert materials such as sawdust, straw, and forms of silica, have been successfully used. A fundamental condition for success is the provision of a seedbed which will hold moisture but not hold it to such an extent that there is little room left for aeration. Nor is the seedbed considered to have no value as a nutritive *medium*. Dr. Gericke recommends the addition of nutrients to the moist seed-bed to cover the transition period during which plants are developing a more complete dependence upon the nutrient solution below; for shallow rooted crops this is indispensable and for deep-rooted crops it is useful inasmuch as it helps to develop lateral roots which will provide a stronger anchorage for the plants.

When the severe losses of fertilisers in the soil are considered, particularly the loss of nitrogen by leaching and of phosphates by fixation, this alternative method of cultivation would seem to possess a very real advantage over agriculture. Not only can these losses be avoided but a greater supply of nutrients in the same space can be given; to quote Gericke, a cubic foot of nutrient solution gives approximately six times the amount of nutrients (and water) that will normally be held by a cubic foot of soil. Of course, the concentration of the nutrient solution that can be used is limited by osmotic pressure consideration —too strong a solution could extract water from the plant and cause wilting—just as in agriculture or horticulture the rate at which soluble fertilisers may be added is limited; but such an abundance of water is always present that this danger is quite remote.

The principal problem with nutrient solutions is the arrangement of an effective nutrient balance. Gericke has classified the nutrients into three groups: (1) those

which are needed as major plant-foods and of which the plant will take up excesses if available; (2) those which will not be taken up in excess but only according to need: and (3) those which are needed in small amounts and excesses of which might be toxic. The grouping of the various nutrients in this way follows the well-known pattern of soil chemistry. Group 1 comprises nitrogen, phosphorus, potassium, calcium and magnesium; Group 2 is sulphur only; Group 3 comprises boron, iron, manganese, copper, and zinc. It is beyond the general aim of this summary to discuss actual formulae for solutions, but the practical basis for designing effective nutrient balances would seem to be a compromise between (*a*) the actual nutrient balance in the known composition of a well-grown plant, and (*b*) the plant's tendencies to absorb Group 1 nutrients too readily. For example, nitrogen might be abnormally taken in as compared with other nutrients; so that a partial supply of nitrogen might be advantageous in the initial balance, with a further supply to be added at some later stage of solution adjustment. Obviously the trace-supply of the potentially toxic nutrients must be carefully controlled within known boundaries. Subject to these safeguarding principles, Dr. Gericke's early work established that nutrient concentrations did not have to be meticulously accurate in the decimal-point sense, although the laboratory exponents of water culture tests had always supposed this to be necessary.

An Impressive Catalogue

On these general principles—though, of course, with much trial-and-error attention to practical and subsidiary details—Dr. Gericke successfully raised innumerable kinds of plants—potatoes, tomatoes, the root vegetables, the cereals, cotton, sugar-beet, herbaceous flowers, tuber- and bulb-flowers, and so on. He has recorded an extensive catalogue of cultural achievement. The question is, how does soilless production compare with normal production?

First, there is the capital outlay. Gericke's estimate (pre-war) is that an acre of basin-space costs 50 times the normal price of an acre of farm land. In special cases, of course, this kind of comparison may not be valid; there may be the personal condition that suitable land is not available at the spot where cultivation is desired, or there may be a more general and geological condition that the soil available is not capable of use for agriculture. But against the background of normal agriculture in temperate countries this comparison of initial 'overheads' has to be faced. The figure given by Gericke is obviously a very rough guide. There is no fixed average cost of land if we take into account the all-important variation of inherent fertility; and the cost of the materials and labour used in constructing a series of tanks or basins will vary according to economic factors that are 'outside' agriculture. Little more can be said except that it takes much more capital to set up a 'hydroponicum' than to acquire a similar area of soil.

Clearly, then, area for area, soilless cultivation must produce much greater yields. Here the nutrient solution method possesses one great advantage over soil cultivation. In the soil plants must be spaced so that each root system has a large enough 'zone of occupation' within which to acquire its food supply and moisture; and also,

FIG. 1.—The fundamental facts upon which soilless cultivation is based were discovered about the middle of the last century. Professor Sachs, a bust of whom is seen here, published in 1860 results of experiments which demonstrated, to quote his words, "that land plants are capable of absorbing their nutritive matters out of watery solutions, without the aid of soil, and that it is possible in this way not only to maintain plants alive and growing for a long time but also to bring about a vigorous increase of their organic substance, and even the production of seeds capable of germination."

in practice, within which to compete in this task with alien weeds. But when each plant has its root system dipping into a complete nutrient solution, the concentration of which can be maintained or adjusted at any time, there is *theoretically* no need for lateral spacing; in a condition of nutrient abundance root proximity does not create competition. In practice, the closeness with which plants can be packed in the litter-bed above the solution depends upon (*a*) the lateral spread of the upper parts of the plants, (*b*) the effect of the degree of closeness upon harvesting operations, and (*c*) the effect of this closeness upon the supply of light to the plants.

Dr. Gericke compared soilless results—for his particular climatic conditions—with agricultural or horticultural results by grouping crops as follows: those which cannot be packed more closely than in soil culture, such as most of the farm cereals and sugar cane; those which can, such as potatoes and most of the gardener's vegetable crops; and those which can be *mixed-cropped* closely so that the total cropping per unit of area is greater than the normal rate of cropping from soil. And it is within this third

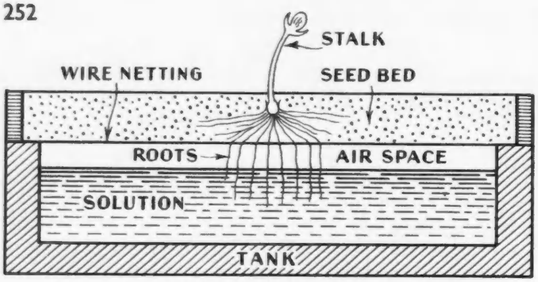

FIG. 2.—Large-scale soilless cultivation using tanks and culture solution is essentially the same as Sachs' technique. For the seedbed a variety of porous materials have been used—leaf mould, peat, sawdust, wood shavings and straw while spun glass has also been tried. (*After Gericke.*)

group, by mixed or multi-cropping, that the most impressive results have been recorded.

The success of multi-cropping depends upon choosing partner crops which will not compete for a full light requirement at the same time. Clearly this sort of arrangement is only likely to be effective when the local climate enables plants to develop rapidly and when the light supply is consistently strong, conditions far more attainable in California than in Britain. In two experiments quoted by Gericke, with the yields expanded into a per-acre basis, 40 tons of potatoes and over 200 bushels of sweet corn were grown; and 50 tons of potatoes and 100 tons of tomatoes.

There may be more economic scope for soilless cropping in the specialised horticultural field. Gericke has pointed out that the comparison of initial outlay charges is much less if made against the normal costs of setting up greenhouses and greenhouse beds; and if under glass and with artificial heat crops are grown for specialised and 'out-of-season' prices, hydroponics may successfully compete with the soil-based nurseryman. One cannot help reflecting, however, that the presence of so much moisture under glass could in practice lead to favourable conditions for many troublesome leaf- and stem-fungoid diseases, the control of which might then introduce a fairly heavy running cost.

But, whatever method of cropping is adopted, it seems certain that the soilless cultivator must inevitably choose crops that obtain a high market price. This indicates, therefore, that hydroponics is unlikely to compete with agriculture; but that it cannot be ruled out as an effective method of producing market-garden foods, glasshouse crops, and flowers. Nevertheless, this is a limited summing-up in which the background of comparison is an active cultivation of a fertile natural soil.

What of regions where there is all the light intensity required for close-packed soilless culture yet where the soil is often of low fertility or even of no useful fertility at all? In *Science for the Citizen* Professor Hogben suggested the setting up of hydroponic tanks in the Sahara desert; and a joint consideration of India's food situation and the poor cropping capacity of much of her soil points to an enormous opportunity there for hydroponic 'farming'. In many parts of the world where the sun's light and heat is particularly favourable to hydroponics the soils are desiccated and low in organic matter; and the setting up of large hydroponic systems might be reasonably comparable in costs with irrigation, natural humification, and other uphill methods of restoring fertility.

Turning from Dr. Gericke's pioneering work in California to British efforts, we find considerably different experiences. The tank-culture method has been a failure in our climate. Prof. Stoughton of Reading University, a leading investigator of this problem, attributes this to our low light intensity and to a difficulty in securing sufficient aeration of the roots. It does not seem clear to the writer why this latter factor should so markedly depend upon climate; however, it is reported that even when forced methods for aeration have been employed the results have not been satisfactory.

As a result British attention has been directed to the sand culture method; that is, to replacing the soil with an inert medium such as sand, cinders, or even part-peat mixtures, and supplying the nutrients by periodically percolating a solution through the bed The chemical nutrients have even been added in dry form to the beds and then watered in. A sub-irrigation method has also been developed; here the nutrient solution is pumped up into the bed, then allowed to flow back by gravity into a supply tank for further use at a subsequent pumping. In all these methods the bottleneck of poor aeration is overcome. The sub-irrigation method, though more expensive to set up, possesses two obvious advantages—it has a wide range of controllable flexibility, and there is little loss of unused nutrients in drainage.

FIG. 3.—Here is the way Sachs grew his plants without soil.

Satisfactory plant-growth of many kinds has been achieved by these British methods; indeed, such methods have also been successfully used in America by Gericke and other workers. But there still remains the economic necessity to obtain a high rate of cropping by close packing, and inevitably it seems doubtful whether our quota of sunshine is sufficient for real success. Stoughton has reported the interesting case of gerberas; these are flowers which are difficult to grow successfully in soil, but for two years gerberas were successfully cultivated by sand culture though the results obtained in the third year showed some deterioration.

A not unnatural query is frequently raised about the nutritive value of crops produced without soil. Here analyses for carbohydrate, protein, minerals, and vitamin C have shown no differences between soil and soilless produce. Gericke has recorded nutritive superiority for hydroponic-raised tomatoes so far as mineral values are concerned, as is shown in the table on the opposite page.

The main point would, however, seem to be that the elimination of the soil does not cause nutritive deterioration; at any rate, so far the recognised laboratory tests for nutritive values indicate.

It is not entirely irrelevant to mention a fairly new development in fertiliser practice, the distribution of liquid-type fertilisers. Strong solutions of nutrient chemicals are being marketed for dilution and application much in the same manner as the old-fashioned liquid manures of gardeners. Many commercial market growers have adopted this method of fertiliser addition with success especially in greenhouse cultivation. In terms of nutrient cost per unit, these liquid bases for manures are more costly than solid fertilisers since even with strong solutions a large accompanying amount of water has to be packed and transported; but despite this, the results obtained by practical growers have led to an expanding demand. When powerful soluble fertilisers such as ammonium phosphate, triple superphosphate, potassium nitrate and phosphate, and urea are liberally available, it would seem more economic for both manufacturer and consumer to develop the use of solid bases for liquid fertilisers; the grower could then add all the water required according to a simple instruction of so many gallons to so many pounds of the concentrated mixture. Both here and in America it has been frequently reported that fertiliser applications in dissolved form are more efficient, quite small amounts of nutrients yielding maximum crops. The practice would seem best suited to (*a*) greenhouse work where the heavy plant demand for water so often vitiates solid fertiliser results, (*b*) as top-dressings for summer crops in dry weather, and (*c*) where the fertiliser user is inexpert and tends to over-use solid fertilisers. Indeed, the success of liquid fertilisers may well have been considerably influenced by this last factor, for in many otherwise efficient market gardens and nurseries there is a great deal of fertiliser misuse. This would explain why some research stations tests have shown only small degrees of superiority for liquid fertiliser applications, for in such comparisons the solid fertilisers will undoubtedly have been expertly chosen and applied.

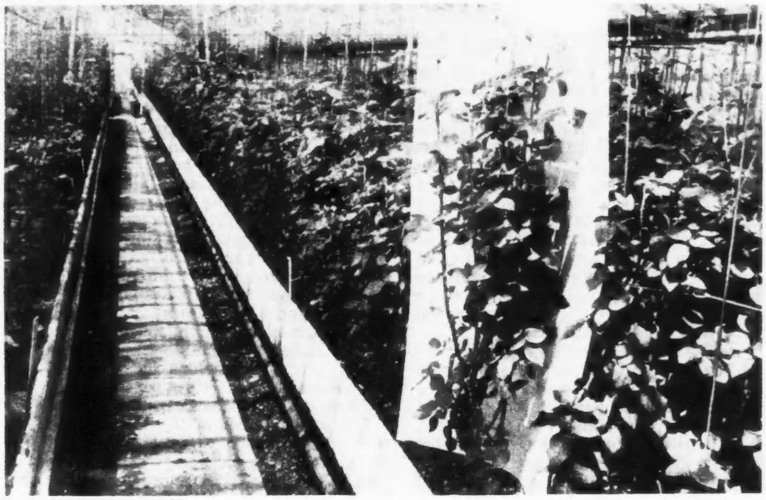

FIG. 4.—These roses were grown in gravel in Ohio State University greenhouses by the sub-irrigation system of soilless cultivation.

To sum up, it seems that much of the popular enthusiasm for hydroponics is exaggerated. As a hobby for the gadget-minded, or as a means of producing what might be called luxury vegetables or flowers, there may be some future for the various methods in this country, particularly for sub-irrigation sand or clinker culture. Agriculture is certainly not threatened. But, beyond this negative judgment, there are the mightier prospects of hydroponic cultivation in those parts of the world where the sunlight and heat are intense and where, for that very reason, the soil is infertile. Large-scale development of this kind might be undertaken if it was found that the general malnutrition of peoples who live in or near these regions cannot be remedied by adequate imports of food from the world's fertile regions. Hydroponics may remain little more than a curiosity; or it may become a major scientific contribution to the world problem of nutrition, a method of harnessing the sun's energy in areas where it is at present entirely wasted.

	Potash	*Phosphate*	*Magnesia*	*Sulphate*	*Lime*
Soil-raised	·99	·21	·05	·06	·20
Soilless	1·63	·33	·10	·11	·28

A remarkable wartime venture into the field of soilless culture was made by the U.S. Army after they 'borrowed' Ascension Island from Britain and developed it as an air base. There is practically no soil on the island except on Green Mountain, where the few residents have vegetable gardens and pasture their sheep. The Air Quarter-master of the U.S. Army Air Forces chose Ascension for his first large-scale test of soilless cultivation of salad crops, such as lettuce, tomatoes and cucumbers. The same method was tried on Iwojima, and other 'hydroponic' experiments have been made on Coconut Island and in British Guiana. On the strength of their success the U.S. Army is setting up acres of sub-irrigation basins in Japan. A well-illustrated account of 'Hydroponics Station No. 1' as the Ascension experiment was called can be found in *The National Geographic Magazine*, August, 1945.

The British Air Ministry is also interested in the possibilities of soilless cultivation.

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Scientific Problems of the Empire

It was scarcely a coincidence that the Empire Scientific Conference (held in London, Cambridge and Oxford between June 17 and July 8) should have been organised by the Royal Society so soon after World War II. Wartime necessity brought into being a liaison between Empire scientists far closer than anything that existed before the war, and with the growth of that liaison came a greater realisation of the number and variety of Empire scientific problems requiring urgent solution, problems that can be tackled only if there is close co-operation between Empire scientists.

It is a safe generalisation to say that big concentrations of scientists are found only in those parts of the world that have a high degree of industrialisation. Most of the Empire is agricultural in its economy, not industrial, and so not only is the distribution of scientists patchy over the Empire as a whole but it is also very thin in many places. Britain is short of scientific manpower, but a much bigger shortage is apparent if the Empire is considered as an entity. How to make the most effective use of the scientists available within the Empire for the solution of immediate and urgent problems was one of the dominating themes of the conference. The interchange of scientific staff between the countries of the Commonwealth was one aspect of this theme, and here the discussion was on familiar lines and the recommendations the obvious and predictable ones. A Commonwealth Centre, which would most appropriately be located in London, was suggested to organise such interchange. This Empire G.H.Q. might also organise a network of information services throughout the Commonwealth.

The conference devoted a great deal of attention to the very basic subjects of food, nutrition and agriculture. The great disparities that exist between the different parts of the Empire was brought home by an Indian speaker who contrasted the aim of the nutritionist in the advanced countries of the Empire to secure *optimum* diets whereas India was concerned with preventing starvation.

Food and Agriculture

An increase in food production can come only from more scientific agriculture. The greater use of fertilisers and an extension of plant breeding and animal breeding were advocated. The plant breeder is short of raw material for crossing and selection, and it was urged that plant collecting expeditions similar to the prewar expeditions that were sent out to collect potato species should be organised. During the war a scheme was started whereby the most appropriate experimental stations of the Commonwealth undertook to maintain live collections of particular crop species and varieties.

Sir Edward Salisbury, director of the Royal Botanic Gardens, Kew, instanced the collection of cotton plants in the Sudan; cocoa plants in Trinidad and in the Gold Coast at Tafo; banana collections in Jamaica and in Trinidad. "Ideally we ought to collect everything that is of economic importance and scientific interest, for who can foretell that what appears to be a useless species of genus today may not, like *Penicillium notatum* (the mould that yields penicillin), be of prime importance tomorrow" said Sir Edward Salisbury, emphasising the need for more taxonomists. At the same session the importance of genetics was stressed.

Delegates were reminded how urgently better crop plants were required when the director of the Plant Diseases Division of New Zealand's Department of Scientific and Industrial Research told how the present varieties of potato cannot resist fungal attack and yield a mere 4½ tons an acre as against the 10-14 tons that used to be obtained in New Zealand.

The improvement of livestock, it was said, is seriously hampered by our ignorance of the physiology of domestic animals. One way of improving native breeds of livestock is to import breeding stock from the United Kingdom for crossing purposes, but before this can be successful it has to be understood how breeds adapt themselves to hot and humid climates.

In many parts of the Empire malnutrition is common. This was the theme of Dr. B. S. Platt's paper on the nutritional status of the colonial natives. He mentioned several steps that could be taken quickly to remove gross malnutrition. In communities suffering from beri-beri the parboiling of rice should be introduced; where there is a shortage of B_2 vitamins, fermented foods, food yeast and skim milk powder should be brought into use. Iodised salt should be administered or iodine added to the drinking water to eliminate goitre.

Soil Erosion

Soil erosion represents a threat to Empire agriculture. In South Africa, for instance, soil erosion is capable of causing a national catastrophe which can only be avoided if soil conservation measures costing £100 million during the next 20-25 years are adopted. In the session on soil conservation the importance of soil surveying was repeatedly stressed.

Speakers at the session devoted to the mineral resources of the Empire drew a gloomy picture. The reserves of many key minerals are dwindling rapidly; within twenty years, for instance, the Empire's proved lead resources will not meet the demand at the present rate of consumption, it was stated. The same is true of zinc.

The development of mineral resources depends to a large extent upon the state of geology. The conference was left in no doubt as to the great lack of geologists. One gathered that British geological science had developed in response to the economic needs of Britain, not those of the Empire, and an Australian geologist said quite bluntly that geological research in Britain failed to supply the looked-for lead to Empire geologists. Australia's geologists, he said, were raised, particularly in economic geology, on a diet of foreign text-books while many had taken to publishing their papers in American instead of British journals.

Chemurgy

Chemurgy, the application of chemical technology to the elaboration of agricultural and forestry products, is likely to be of great economic importance to the Empire, and directions in which it offers promise were indicated by several speakers. Professor J. L. Simonsen, research director of the Colonial Products Research Council, which was set up during the war, spoke of the likelihood in the near future of surpluses of cane sugar and molasses and how these might be utilised. Fermentation processes needed studying, and he referred to the recent formation of a Colonial Microbiological Research Institute under the direction of Dr. A. C. Thaysen. He doubted the economic soundness of processing oil seeds not in the country of origin but in more highly industrialised countries; the cake left after pressing out the oil could be used, he said, to provide food for stock and so improve the productivity of the already impoverished soils. He pointed out the way in which technological progress could itself create serious problems; he instanced the synthetic manufacture of vanillin which endangered the clove-stem oil industry so vital to one of our colonies. Here the chemist would have to find a new use for the unwanted oil, a problem which the Colonial Products Research Council was now investigating. Similarly, synthetic rubber production creates difficulties for plantation rubber; rubber planters will have to concentrate on trees giving the highest yield and must attempt to secure the most economical use of by-products —for instance, valuable oil could be extracted from rubber seed. The demand for derris is going to be lowered by the introduction of synthetic insecticides like DDT and gammexane, and chemotherapy is likely to result in diminished interest in drugs derived from plants, said Professor Simonsen.

Radar and Aerial Survey

Modern methods of mapping and exploration from the air provided the subject for discussion at another session. Economic development of the Empire in many places awaits the completion of geological surveying, but neither the geologist, nor the civil engineer and the mining engineer, can get to work until topographical maps have been produced. By traditional methods these will take literally hundreds of years to complete. Aerial photography coupled with radar offers a way out of this difficulty. The radar method, which is already being used to control air survey in West Africa where tropical forest makes ordinary survey methods almost impossible, was described to the delegates in detail by Lieut.-Col. C. A. Hart, of the British Army's Directorate of Military Survey.

The grave danger of disease spreading from one part of the Empire to another

was emphasised in the session devoted to the etiology and control of infectious and transmissible diseases. This danger was seen by the conference as part of a larger, world problem, and a recommendation was made to the effect that the United Nations Organisation should set up an international sanitary authority that would be responsible for preventing the spread of diseases from endemic to non-endemic areas. This authority should lay down vaccination regulations for travellers, and ensure that planes and ships did not transport disease-carrying insects such as the mosquito. The possibility of using paludrine to clear malaria out of regions where it is now endemic was mentioned, as was also the danger of producing a race of malarial parasite resistant to the drug.

The effect of the climate on the human body was studied in Britain and Australia during the war with military ends in view, and the conference agreed that climatological laboratories should be set up in different parts of the Empire, notably in Africa and the Far East, so that this line of research could be extended. Air conditioning should be studied co-operatively by the countries of the Commonwealth. It was pointed out that research on output in industry in the Tropics needs to be done; so far the subject is practically untouched.

Standards of measurement were discussed, and it was recommended that the slight difference in the values of the yard and the pound at present used in the Commonwealth and in the United States should be eliminated. The conference advocated the adoption of the metric system in all fields of science.

The future of fundamental research was the subject of one particularly interesting session. For this session a report on British needs in this connexion had been prepared. (A note on this important report will be published in our September issue.)

The Royal Society conference has been followed by an official Commonwealth Scientific Conference, at which ways of implementing recommendations made at the unofficial conference were discussed by representatives of the Dominion Governments. A record of the official conference is to be published, probably in the late autumn.

Disney's Health Films

Application of the most recent advances in medical treatment is usually delayed five to ten years in Britain, and considerably longer in some other countries. This is due to the difficulties of retraining doctors once qualified, and of persuading the public to accept wholeheartedly new forms of treatment. Intelligent use of the film on a national basis could materially improve this state of affairs: doctors could be shown regular refresher films locally (the Ministry of Health's film *Scabies* is an example); whilst films designed to instruct the public should show the principal features of the anatomy and physiology of the healthy human body, and provide an insight into the ways in which diseases upset the normal organism. Such information would enable the man in the street who falls ill to take an intelligent part in his cure instead of being expected to follow blindly the instructions given him. An increasing realisation that the patient can be cured better and quicker if he is helped to cure himself actively lies behind the modern fashionable concepts of rehabilitation and occupational therapy.

The Medical Department of the Office for the Co-ordination of Inter-American Affairs, which is setting up numbers of Health Centres all over the Americas, realised that to work efficiently and economically these centres must operate amongst a receptive and relatively knowledgeable people, for a health centre established in a community which regards an epidemic as an act of vengeance from an offended god could make but little headway. So an educational programme has been mapped out in which films play a part.

Since they were to be presented to illiterate peasants it was decided to use a sound-track commentary; colour film was chosen because of its greater appeal, and the cartoon technique was preferred because it enables a more fundamental approach to be presented with unnecessary details eliminated. Since many of the concepts would on first impact be unacceptable when judged by local prejudices, humour was thought necessary; and because the films were to be presented to a wide variety of nationals, similes of an international character only could be used. With these points fixed, it was decided to entrust the design and production of the films to Walt Disney, for it is commonly agreed that his type of humour goes down well in all countries and with all people. The films were planned as a series, designed to be shown in a given order, and since they were to be educational the decision was made to accept Western standards of civilised behaviour as the norm and to present facts against a background of Western ideas and habits.

Eight of these films were shown in Britain recently. *The Human Body* shows that man depends on a healthily functioning body for his existence and then gives a simple description of the concept of a skeletal structure to reinforce his muscle and skin, the purpose of food, the mechanism of digestion, and the function of breathing. *What is Disease?* introduces the concept of magnification and the function of the microscope; microbes, what they are, how they grow, how they kill you, how they spread, and how they can be combated. *How Disease Travels* expands one of the themes of the previous film; it shows how microbes excreted in man's waste are carried to every member of the community by water, flies and dust, and it shows how to build a latrine. *Insects as Carriers of Disease* takes up another facet of the story, showing the way the fly, mosquito and louse are each responsible for carrying a definite disease round the community. *Cleanliness Brings Health* compares two families, one of which washes regularly and uses a proper latrine, and the other does not. *Hookworm* shows how the worm gains entry through bare feet, and how the life cycle with excretion in the faeces leads to reinfection; the morals—wear shoes and build a latrine—are drawn. *Tuberculosis* gives a clear illustration of the nature of the disease, its spread and the home measures that can be taken to isolate and cure the patient. *Infant Care* is a light demonstration of the value of balanced diet in pregnancy, and of mother's milk and careful weaning. *Environmental Sanitation* and *Planning for Good Food* have not yet been seen.

Taken as a whole, the medical data of this series are good and accurate, the method of introduction of basic concepts is well thought out and the constant reiteration of the importance of proper latrine facilities valuable. But Disney has not put his best into these films: they are crude rather than simple, and some of the images are over-stylised. These films were originally designed for illiterate peasants who are to see them on a mobile projector in makeshift halls or at night in the open; many will be seeing a film for the first time in their lives. They will not understand them, for although the information has been carefully thought out on paper, advanced cinematic conventions are used to present it. We are apt to forget that film presentation has evolved conventions of its own: for example, the use of a close-up immediately after a long-shot represents to us a sequence—we connect the second with the first. But to the unsophisticated peasant these two shots may have no connexion whatever, he may build up no story by synthesising the two. Furthermore these films contain too much: they run for an average of ten minutes each, yet each is packed with information and even an expert finds their tempo fast. Two facts and one exhortation in ten minutes would be quite enough.

But these films will be good fare for training schoolchildren and for health-workers; and since the international approach has been well maintained they will be useful over a wider field than the Americas.

Brian Stanford, M.R.C.S., F.R.P.S.

(This review is contributed by arrangement with the Scientific Film Association.)

Far and Near

Newton Tercentenary Celebrations

"THE war prevented an international celebration in 1942 of the 300th anniversary of the birth of Isaac Newton. The Royal Society of London has taken this opportunity of inviting the national academies of science of the world to join with it in paying homage to his memory." Thus ran the President's (Sir Robert Robinson) foreword to the week's programme. But the celebrations served another purpose. It was the first great international scientific conference in Britain since the war and the organisers wisely used the historical reason as the opportunity to gather together 150 foremost scientists from 37 countries to exchange their views and experiences.

The occasion was used, also, for an extraordinary meeting of the Society for admitting the Foreign members elected in recent years.

Possibly the important event of the celebrations was the announcement that the Government was prepared to implement the proposal, which originated in astronomical circles and which was transmitted by the Royal Society to the authorities, that a Newton Observatory should be set up. This observatory, it is planned, will have a hundred-inch reflecting telescope, and will be sited near to the Royal Greenwich Observatory at Herstmonceux in Sussex.

Mines and Countermeasures

THE new exhibition at the Science Museum enables the public to see representative naval mining material used by the British and Germans during the recent war, and also to see the major method of ship protection employed against magnetic mines, 'degaussing'. The naval mining material includes the first German magnetic mine recovered intact.

Didcot Gets Under Way

A LOW-POWER graphite atomic pile has been designed for experimental work and should be in operation at Harwell by the end of this year. This statement was made last month by Professor J. D. Cockroft, director of the Atomic Energy Research Establishment, which has taken over Harwell airfield near Didcot. He added that a higher powered graphite pile of a type similar to the Clinton pile described in the Smyth Report is also being built. This will provide intense sources of radiation and will produce large quantities of radioactive substances for scientific research and medical work.

About 250 scientists have been appointed to the staff of Harwell. At present only 35 scientists are actually working at Harwell owing to the limited accommodation available. Until new buildings have been completed a number of the staff are working in Canada where there is a fine group of nuclear physical laboratories at Chalk River and where heavy water piles have been constructed. The rest of the staff who have been appointed are doing their work in other Government establishments such as Telecommunications Research Establishment, Malvern, and the Royal Aircraft Establishment at Farnborough.

Associations of Scientific Workers Federate

AN International Federation of Scientific Workers has been set up with Professor Frederic Joliot as president.

Night Sky in September

The Moon.—Full moon occurs on September 11d 09h 59m U.T., and new moon on September 25d 08h 45m. The following conjunctions take place:

September			
21d 04h	Saturn in conjunction with the moon	Saturn	4° S.
27d 13h	Jupiter ,,	Jupiter	3 S.
27d 16h	Mars ,,	Mars	4 S.
29d 00h	Venus ,,	Venus	7 S.

In addition to these conjunctions with the moon the following conjunctions occur: September 4d 03h, Venus in conjunction with Jupiter, Venus 3·5° S.; September 25d 04h., Mars in conjunction with Jupiter, Mars 1·1° S.

The Planets.—Mercury rises just before 4h on September 1 and can be seen in the eastern sky. The planet is in superior conjunction on September 14 and is not favourably placed for observation during the remainder of the month. Venus can be seen in the western sky, her times of setting being 19h 51m, 19h 12m, and 18h 27m at the beginning, middle and end of the month respectively. The planet attains her greatest eastern elongation on September 8 and her stellar magnitude varies from −3·9 to −4·2 in September. Mars is too close to the sun for favourable observation. Jupiter sets at 20h 11m on September 1 and is too close to the sun to be observed very well during the month. Saturn rises at 2h on September 1 and at 0h 19m on September 20 and can be seen in the morning hours in the constellation of Cancer. The stellar magnitude of the planet is 0·5 during September.

Autumn equinox occurs on September 23d 16h. At this time the length of the days and nights is the same all over the world—twelve hours each.

TIME AND THE BIOLOGIST —*continued from p. 249*

the time-rate of evolution is not necessarily or primarily controlled by mutation rates. But he emphasises that so little is known of mutation rates that it is impossible to arrive at definite conclusions. It is, however, generally not inconceivable that species which have longer individual lives and slower generations also have higher mutation rates. If so, mutation rates and lengths of generations would compensate each other, and the progress of evolution would then appear as if it was a function of absolute time. This is one possible explanation of the phenomenon in question.

It can hardly be denied that the application of geochronology to biological evolution opens fresh possibilities of tackling the problem of evolution. Experimental workers on evolution have for a long time expected the palaeontologists to give them information about actual rates of evolution. Some tentative data of this kind are at last forthcoming.

The implications of research of this kind may prove to be far-reaching. There is the old problem of so-called Lamarckism. Competent geneticists have admitted the possibility that (to quote a remark of Professor Haldane) "the effects of use and disuse may be impressed on a species at a rate not susceptible of experimental verification, yet rapid enough to be of importance in geological time".

On the other hand, those who favour Lamarckian views, such as Professor Frederic Wood Jones of the Royal College of Surgeons, have emphasised that the evolutionary processes they have in mind require very long periods of time. It is perhaps not quite out of the question that the geneticist and Lamarckian hypotheses of evolution might eventually be reconciled on the common ground provided by a chronology of evolution.

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NOTE

In the article, 'Time and the Geologist' (DISCOVERY, April, 1946) Fig. 8A requires a minor correction. The arrow covering 20,000 years should be shortened by about one half, to terminate at the last (right-hand) minimum of the curve.

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